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Development of a Ground Test & Analysis Protocol for NASA's NextSTEP Phase 2 Habitation Concepts

Michael L. Gernhardt

Peer-Reviewed Protocol – The contract by which we conduct consistent testing across the contractor configurations

- Protocol includes inputs from multiple stakeholders
  - NextSTEP
  - FCT
  - AES
  - Crew Office
  - HRP
  - Human Health and Performance
  - Operations/MCC
  - ….

- Clearly defined objectives, hypotheses, metrics, procedures, flight rules, and data analysis

- These ground tests and analyses will initially be conducted on a minimum of two, NASA developed configurations in order to train the test teams, and refine data collection and evaluation methods during FY18.

- This protocol will be customized for each specific contractor DSG configuration. The level of detail of these tests and analyses will be a function of the fidelity of the individual contractor deliverables.

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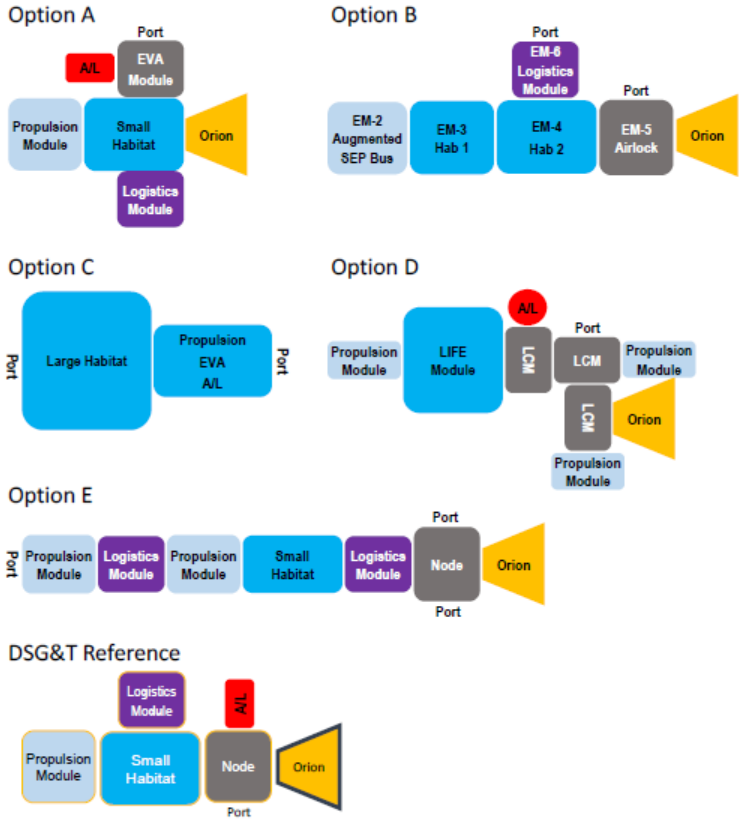
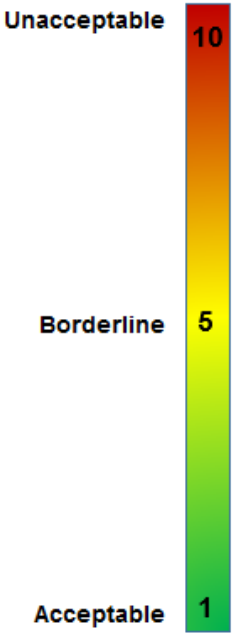
Five Different Contractor Options

- **The Phase 2 RFP focused on getting contractor ideas for what a DSG should be**
  - No Specific Requirements
- **It is critically important for a consistent evaluation that the same core mission is conducted in each of the five contractor habitats**
  - If we do 5 completely different missions in 5 completely different habitats there will be absolutely no basis for effective comparison
- **The purpose of this test and analysis program is not to pick a "winner" but through the testing and analysis define what we like and don't like.**
  - Data is used to inform requirements for Phase 3.



Acceptability Ratings

DSG Architectural Configuration Acceptability Ratings



	A	B	C	D	E
Robotic arm ops	2	8	9	3	9
EVA prep	6	10	2	6	1
EVA	7	3	6	1	8
Meal prep	9	10	6	9	1
Hygiene	1	2	7	6	7
WCS ops	5	4	7	3	2
Suit Stowage	3	3	7	4	8
Sleeping	5	6	2	8	9
Docking and berthing	10	5	2	6	5
Logistics/Trash Stowage	7	6	7	5	10
Simulated contingencies	4	9	1	4	2
Experimental science	6	6	4	5	8
House keeping	2	5	2	3	5
Routine maintenance	2	7	1	4	9
IFM	5	8	7	10	6
Exercise	4	5	10	5	8
PAO	3	10	5	3	10
Medical	7	9	2	5	2

Acceptability Ratings < 4

Acceptable Configurations	Most Acceptable Configuration
A, D	A
C,E	E
B,D	D
E	E
A,B	A
B,D,E	E
A,B,D	A or B
C	C
C	C
None	None
A,C,D,E	C
C	C
A,C, D	A or C
A,C,D	C
None	None
A	A
A,D	A or D
C,E	C or E

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary		Minor improvements desired		Improvements warranted		Improvements required		Major improvements required	
1	2	3	4	5	6	7	8	9	10

HITL Test Conditions

The baseline DSG stack configuration is assumed to be a habitat, airlock, Orion, and logistics module.

- **In FY18 preliminary testing at JSC, two conditions: "Habitat-Centric Function Allocation" and a "Distributed Function Allocation", will be executed to evaluate the allocation of DSG functions across those elements.**
- **Each condition includes four crewmembers, with the differences among conditions reflecting different strategies for distributing the required DSG functions, systems, and subsystems across available elements.**
- **Habitat-Centric Function Allocation**
  - Assume all required DSG functions (e.g. robotic workstation, exercise, science, meals) are co-located in a single small habitat that includes a dedicated equipment lock (E/L)/crew lock (C/L).
- **Distributed Function Allocation**
  - Spread the required DSG functions across available elements; functions, such as exercise, meal preparation, robotic workstation, and science, may be performed in a separate multifunction equipment lock/crew lock element, with the remaining functions in a small habitat

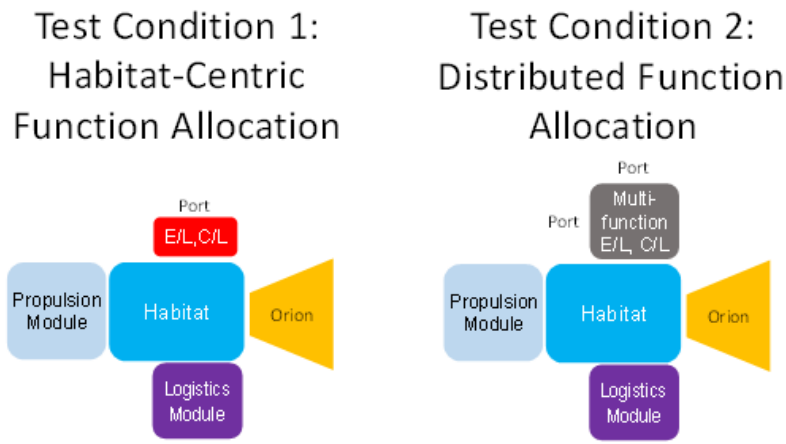
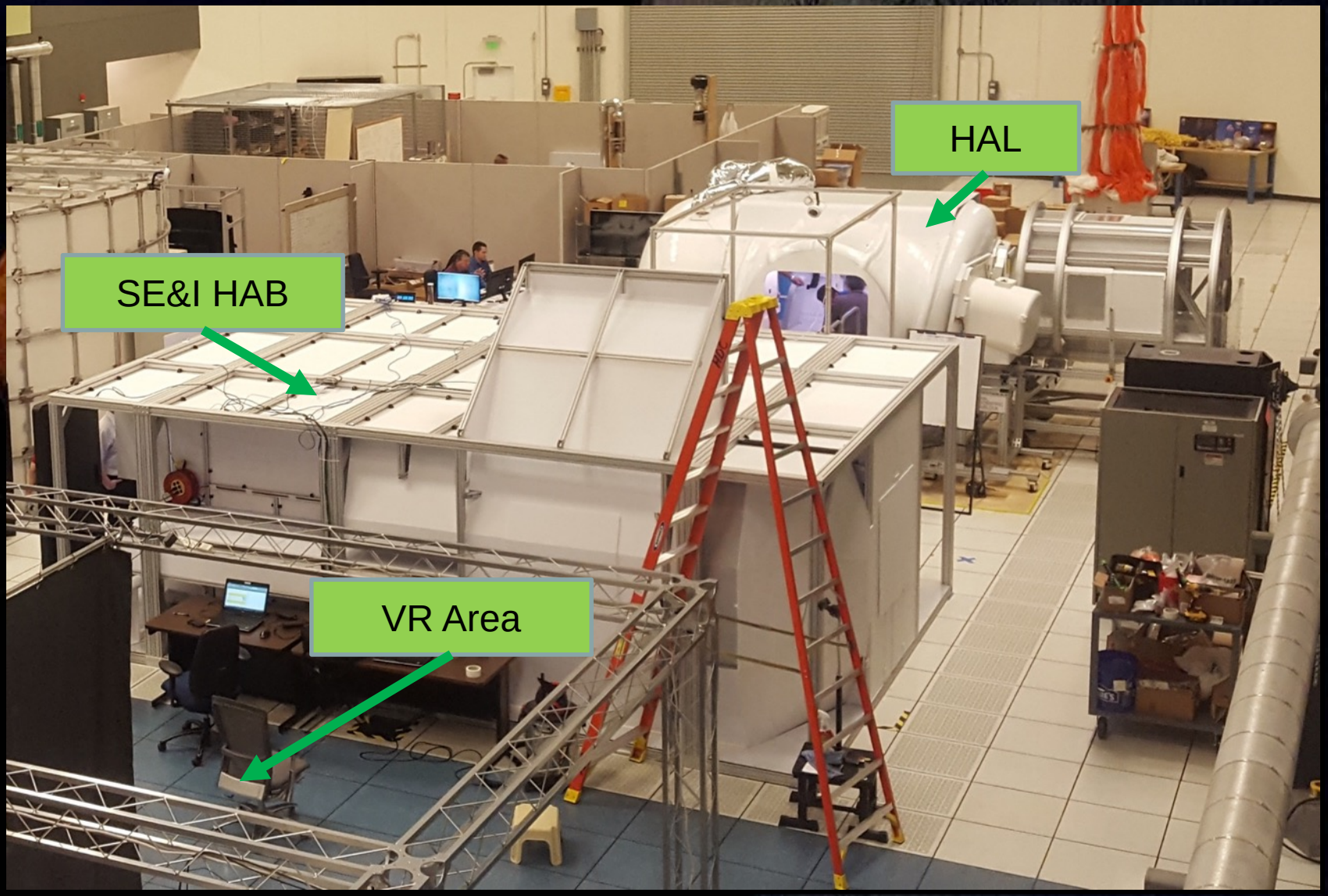
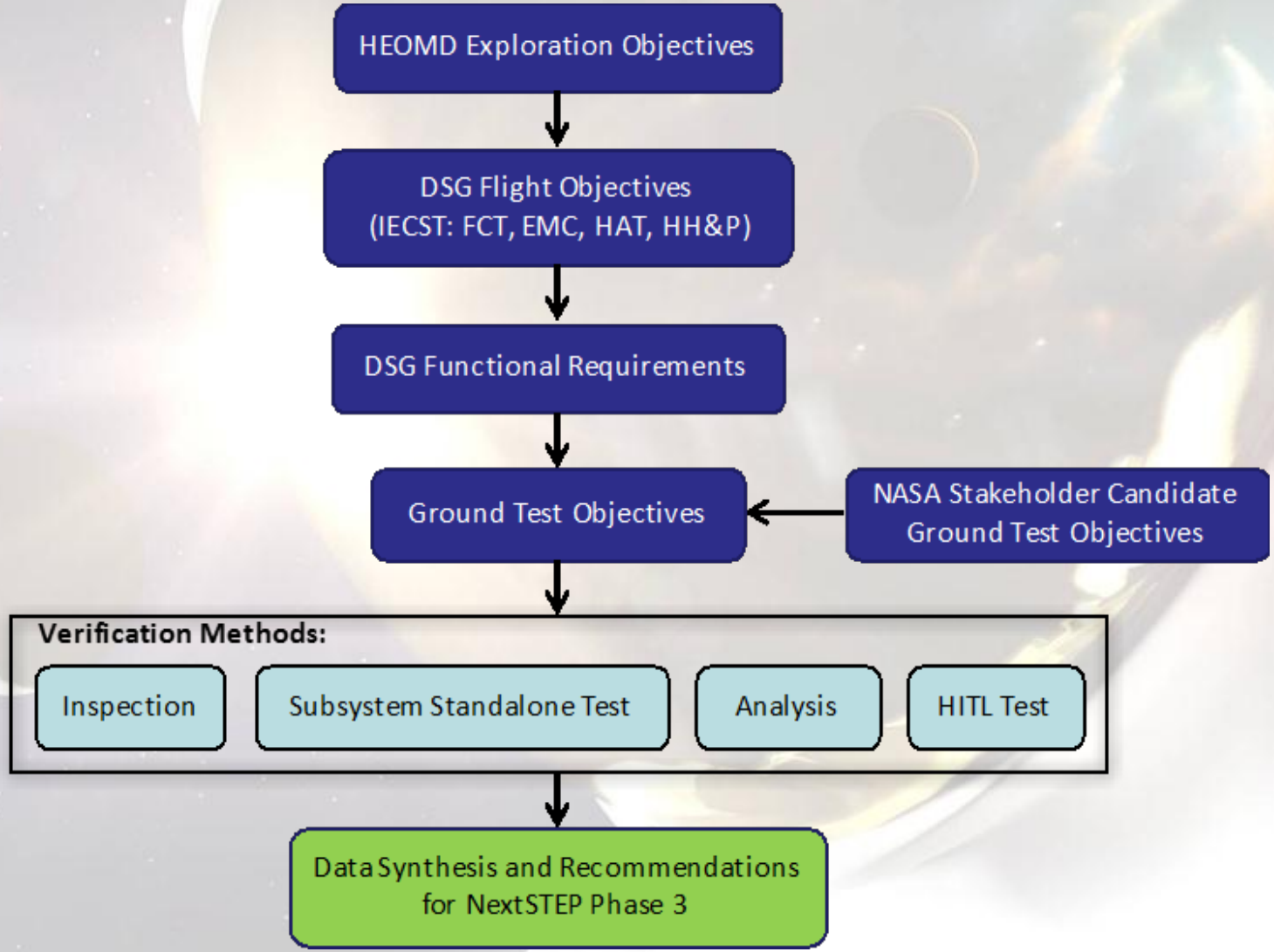


Figure 20. Graphical representation of test conditions 1 and 2 (E/L = equipment lock, C/L = crew lock).

Picture of iPAS Setup in Building 29/JSC



BAA Ground Test and Analysis Protocol Development Process



DSG Draft Functional Requirements Derived Timelines

Stack ID	DSG-Level Functional Requirements	HITL (Single Day/Multi Day) Test Protocol Description/Deliverables	Priority (High, Medium, Low)
DSG-0180	The Deep Space Gateway shall provide integrated vehicle translational control for all docked elements/vehicles.	execute HITL test timeline; use displays and controls to demonstrate translational control for different stack configurations; collect subjective metrics from crew via consensus questionnaires	medium
DSG-0200	The Deep Space Gateway shall provide ECLSS consumables for all docked	execute HITL test timeline; use displays and controls to demonstrate ECLSS	

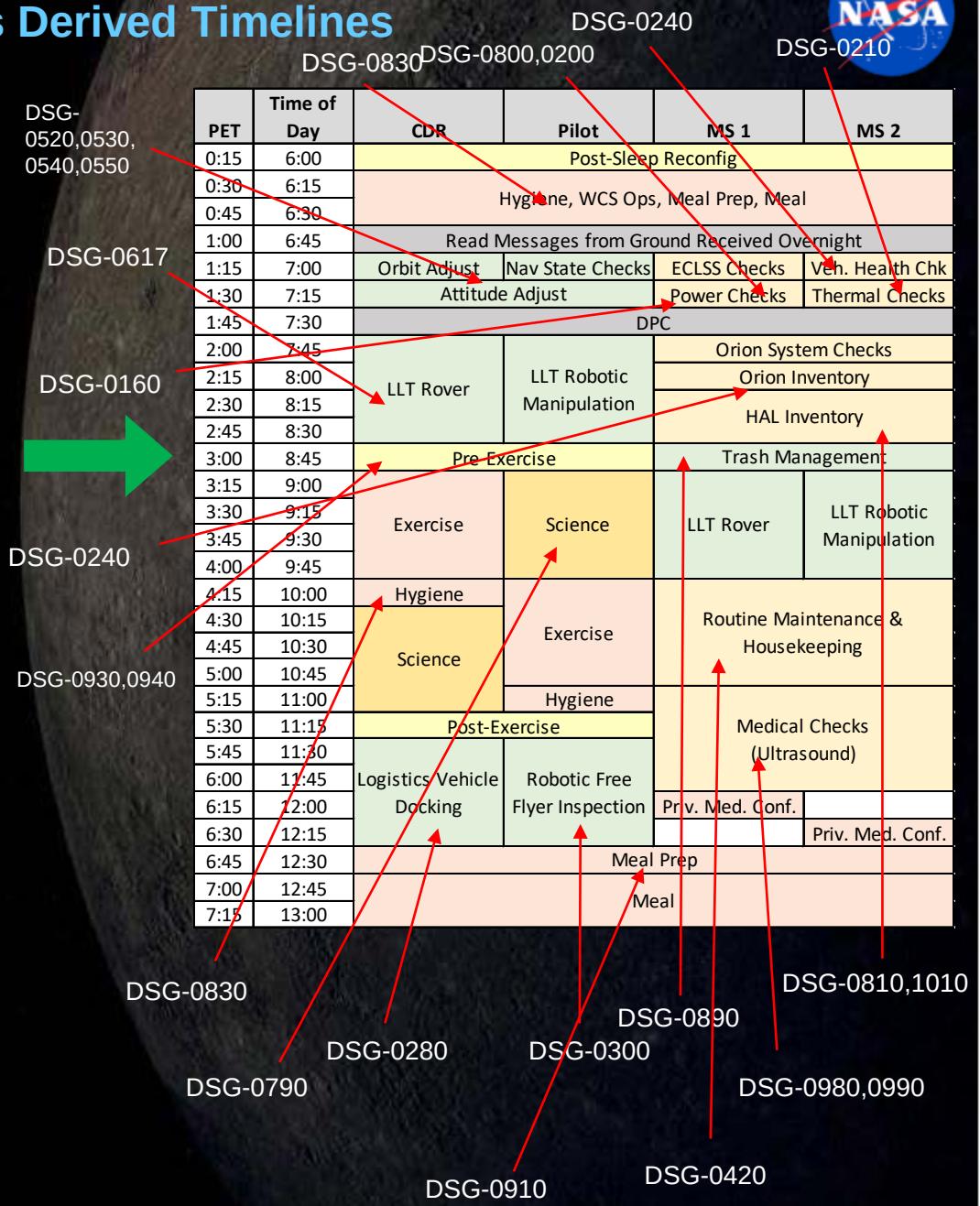
Stack ID	DSG-Level Functional Requirements	HITL (Single Day/Multi Day) Test Protocol Description/Deliverables	Priority (High, Medium, Low)
DSG-0850	The Deep Space Gateway shall provide TBD storage volume for spare parts for 120 crewmember days.	evaluate storage and access of spare parts as part of the HITL timeline; collect subjective consensus ratings and comment via questionnaire	medium
DSG-0990	The Deep Space Gateway shall provide storage for contingency medical response equipment and supplies.	perform contingency medical task as part of timeline; collect subjective consensus ratings and comment via questionnaire	medium
DSG-1000	The Deep Space Gateway shall provide workspace for medical monitoring and countermeasures	perform contingency medical task as part of timeline,followed monitoring and countermeasures; collect subjective consensus ratings and comment via questionnaire	medium

Stack ID	DSG-Level Functional Requirements	Inspection Description/Deliverables	Priority (High, Medium, Low)
DSG-0750	The Deep Space Gateway shall include translation/stabilization aids and restraints to	inspect designs for IVA translation/stabilization aids; assess contractor designs for	high

Stack ID	DSG-Level Functional Requirements	HITL (Single Day/Multi Day) Test Protocol Description/Deliverables	Priority (High, Medium, Low)
DSG-0460	The Deep Space Gateway shall provide an umbilical interface assembly panel to support 2 suits.	provide mockups of umbilical interface panels; evaluate placement of umbilical interface panels to support 2 suits during simulated EVA; collect subjective consensus ratings and comment via questionnaire	high

Stack ID	DSG-Level Functional Requirements	HITL (Single Day/Multi Day) Test Protocol Description/Deliverables	Priority (High, Medium, Low)
DSG-0020	The Deep Space Gateway shall accommodate one 30 day mission per year for up to 4 crew (120 crewmember days).	execute HITL test timeline; record objective metrics (e.g. task time, zone maps for location of crew) and subjective metrics via post-test crew consensus questionnaires, including asking them to extrapolate test time to make judgement about the acceptability of a 30 day duration	high
DSG-0310	The Deep Space Gateway shall support 3 EVAs with two crew within a dedicated EVA week.	**(enhanced mission only)** create mockups as needed to simulate EVA pre/post tasks; execute HITL test timeline; validate timelines for cabin reconfiguration, suit donning, suit doffing, etc.; collect subjective metrics from crew via consensus questionnaires and objective data (e.g. task times, zone maps for crew location); possible use of VR to evaluate external translation paths and restraints	high
DSG-0315	The Deep Space Gateway shall support one contingency EVA per mission.	create mockups as needed to simulate EVA pre/post tasks; execute HITL test timeline; validate timelines for cabin reconfiguration, suit donning, suit doffing, etc.; collect subjective metrics from crew via consensus questionnaires and objective data (e.g. task times, zone maps for crew location); possible use of VR to evaluate external translation paths and restraints	high
DSG-0320	The Deep Space Gateway airlock shall be reconfigurable to support an EVA in 120 minutes or less.	create mockups as needed for HITL testing to simulateall reconfiguration items; perform cabin reconfiguration from habitation to EVA mode and validate concepts/designs and timeline; collect subjective metrics from crew via consensus questionnaires and objective data (e.g. task times, zone maps for crew location); note: Consider 120 minutes or less to be a goal	high
DSG-0360	The Deep Space Gateway shall enable EVA prep times, including suit donning and prebreathe (from exploration atmospheres) in less than 30 minutes (TBR).	create mockups to effectively simulate EVA prep tasks (i.e. donning aids, stabilization aids, suits); execute EVA prep task as part of HITL test timeline; take objective metrics (e.g. task timing, zone mapping for crew location) and subjective metrics via crew consensus questionnaires	high
DSG-0370	The Deep Space Gateway shall enable post-EVA suit doffing and recharge setup in 30 minutes or less (TBR).	create mockups to effectively simulate EVA post tasks (i.e. doffing aids, stabilization aids, suits); execute EVA post task as part of HITL test timeline; take objective metrics (e.g. task timing, zone mapping for crew location) and subjective metrics via crew consensus questionnaires	high
DSG-0410	The Deep Space Gateway shall provide stowage volume for up to 3 EVA suits, and associated consumables and spares.	execute EVA portion of HITL test timeline; evaluate stowage and reconfiguration of the the stack for EVA for different types of suit configurations; collect objective (e.g. task timing, zone mapping for crew location) and subjective consensus ratings and comment via questionnaire	high
DSG-0430	The Deep Space Gateway shall provide stowage volume for air lock contingency and EVA tool bags (e.g., hatch tools) inside the vehicle.	provide mockups of EVA and airlock contingency tools; evaluate stowage volume and access for tools for hatch tools during simulated EVA prep and post; collect subjective consensus ratings and comment via questionnaire	high
DSG-0440	The Deep Space Gateway shall support stowage of nominal EVA tools, including mini workstations, tethers, the pistol grip tool (PGT), inside the vehicle.	provide mockups of nominal EVA tools; evaluate stowage volume and access for tools for nominal EVA tools; collect subjective consensus ratings and comment via questionnaire	high
DSG-0450	The Deep Space Gateway shall provide stowage of two 15-foot (TBR) umbilicals.	develop medium fidelity mockups of nominal EVA umbilicals; evaluate stowage volume, access, and usage of umbilicals during simulated EVA; collect subjective consensus ratings and comment via questionnaire	high

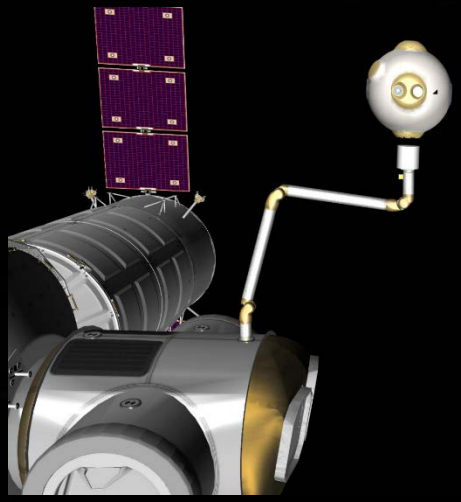
HITL test timeline directly maps to draft DSG functional requirements and stakeholder ground test objectives.



Example Timeline Task –TeleRobotics

- **<u>Strategic Question 12:</u> What robotic assets are needed to support DSG task categories, including, but not limited to, logistics handling, dormancy maintenance, sample return, experiment deploy/recover, EVA support, and aggregation of the DST?**
  - …To understand the requirements for robotic workstations (human factors design, number/location of stations, etc.), specific representative tasks including lunar rover teleoperations and sample return simulations will be performed with HITL testing. The NASA in-house and contractor tests will include different numbers, types, and locations of robotic workstations all used to execute a common representative mission timeline.

DSG ID	Primary Functional Requirements Domain	DSG-Level Draft Functional Requirements	Ground Test Objectives
DSG-0290	robotic operations	The Deep Space Gateway shall provide robotic operations for sample return.	Demonstrate robotic arm displays and controls for capture and berthing of sample return capsules; simulate capture and berthing of sample return capsules
DSG-0617	robotic operations and communication	The Deep Space Gateway shall communicate with the Moon.	simulate and evaluate Deep Space Gateway communicating with the Moon
DSG-0300	robotic operations	The Deep Space Gateway shall provide robotic operations of free-flyers.	Demonstrate robotic free-flyer displays and controls; simulate robotic free-flyer operations



- We can customize the order we execute the tasks to facilitate the best performance within a given habitat layout
- In addition there are blocks (in blue) in the timeline which are variables where contractor unique mission content can be incorporated.
- It is critically important for a consistent evaluation that the same core mission is conducted in each of the five contractor habitats
  - If we do 5 completely different missions in 5 completely different habitats there will be absolutely no basis for effective comparison

CDR	Pilot	MS 1	MS 2
Post-Sleep (Hygiene, WCS Ops, Meal Prep, Meal, Prep for DPC)			
GNC Checks (Nav State, Orbit & Attitude Adjusts)		Hab Systems & Consumables Checks (ECLSS, Power, Thermal, Vehicle Health)	
DPC			
LLT Rover Sim	LLT Robotic Manipulation Sim	Orion Systems & Consumables Checks	
		HAL Systems & Consumables Checks	
		Logistics	
Pre-Exercise Prep and Set-up		Trash Management	
Exercise	Science	LLT Rover Sim	LLT Robotic Manipulation Sim
Science	Exercise	Science	
Post-Exercise Clean-up and Reconfig		Priv. Med. Conf.	
Meal Prep			Priv. Med. Conf.
Meal			
LLT Robotic Manipulation Sim	LLT Rover Sim	Routine Maintenance & Housekeeping	

PET	Time of Day	CDR	Pilot	MS 1	MS 2
7:45	13:45	LLT Rover Sim		Pre-Exercise Prep and Set-up	
8:00	14:00			Exercise	Standalone Assessments
8:15	14:15				
8:30	14:30				
8:45	14:45	Medical			
9:00	15:00			Standalone Assessments	Exercise
9:15	15:15				
9:30	15:30				
9:45	15:45	Science			
10:00	16:00			Post-Exercise Clean-up and Reconfig	
10:15	16:15			LLT Rover Sim	LLT Robotic Manipulation Sim
10:30	16:30				
10:45	16:45	Priv. Med. Conf.			
11:00	17:00		Priv. Med. Conf.		
11:15	17:15	Standalone Assessments	Standalone Assessments	Medical	
11:30	17:30				
11:45	17:45				
12:00	18:00				
12:15	18:15	Meal Prep			
12:30	18:30	Meal			
12:45	18:45				
13:00	19:00	PAO Event			
13:15	19:15				
13:30	19:30	DPC			
13:45	19:45	Daily Habitation Questionnaires and Metrics Ratings			
14:00	20:00				
14:15	20:15				
14:30	20:30				
14:45	20:45				
15:00	21:00				

May Test – Engineering Day 1 (Habitat Only)

PET	Time of Day	CDR	Pilot	MS 1	MS 2
0:15	6:15	Post-Sleep (Hygiene, WCS Ops, Meal Prep, Meal, Prep for DPC)			
0:30	6:30				
0:45	6:45				
1:00	7:00				
1:15	7:15				
1:30	7:30				
1:45	7:45	GNC Checks (Nav State, Orbit & Attitude Adjusts)		Hab Systems & Consumables Checks (ECLSS, Power, Thermal, Vehicle Health)	
2:00	8:00				
2:15	8:15	DPC			
2:30	8:30	LLT Rover Sim	LLT Robotic Manipulation Sim	Orion Systems & Consumables Checks	
2:45	8:45			Trash Management	
3:00	9:00			Logistics Reconfig	
3:15	9:15				
3:30	9:30	Pre-Exercise Prep and Set-up		Lunar Traverse and Sample Collection	
3:45	9:45	Exercise	Telescope Observations		
4:00	10:00				
4:15	10:15			Radiation Vest Assessment	
4:30	10:30	Post-Exercise Clean-up	Exercise		
4:45	10:45	IFM			
5:00	11:00			Housekeeping	
5:15	11:15		Post-Exercise Clean-up and Reconfig		
5:30	11:30	Meal Prep			
5:45	11:45	Meal			
6:00	12:00				
6:15	12:15	Sample Return Sim RMS		Imagery/Charge Reminder	Personal Health Checkout
6:30	12:30			Pre-Exercise Prep and Set-up	Priv. Med. Conf.
6:45	12:45	Personal Health Checkout	Imagery/Charge Reminder	Exercise	Pre-Exercise Prep and Set-up
7:00	13:00	Priv. Med. Conf.	Personal Health Checkout		VR Task
7:15	13:15	Imagery/Charge Reminder	Priv. Med. Conf.		
7:30	13:30	HAB Science Airlock Ops		Post-Exercise Clean-up	
7:45	13:45			VR Task	Exercise
8:00	14:00	HRP Science (Muscle Ultrasound)			
8:15	14:15				
8:30	14:30			Personal Health Checkout	Post-Exercise Clean-up and Reconfig
8:45	14:45			Priv. Med. Conf.	Imagery/Charge Reminder
9:00	15:00	PAO Event Setup			
9:15	15:15	PAO			
9:30	15:30	DPC			
9:45	15:45	Meal Prep			
10:00	16:00	Meal			
10:15	16:15				
10:30	16:30	Daily Habitation Questionnaires and Metrics Ratings			
10:45	16:45				
11:00	17:00				
11:15	17:15				
11:30	17:30				
11:45	17:45				

May Test – Engineering Day 2 (HAL-Hab Distributed)

PET	Time of Day	CDR	Pilot	MS 1	MS 2
0:15	6:15	Post-Sleep (HAL) (Hygiene, WCS Ops, Meal Prep, Meal, Prep for DPC)			
0:30	6:30				
0:45	6:45				
1:00	7:00				
1:15	7:15				
1:30	7:30				
1:45	7:45	GNC Checks (HAL) (Nav State, Orbit & Attitude Adjusts)		Hab Systems & Consumables Checks (Hab) (ECLSS, Power, Thermal, Vehicle Health)	
2:00	8:00				
2:15	8:15	DPC (HAL)			
2:30	8:30	LLT Rover Sim (HAL)	LLT Robotic Manipulation Sim (HAL)	Orion Systems & Consumables Checks (Hab)	
2:45	8:45			HAL Systems & Consumables Checks (Hab)	
3:00	9:00			Trash Management (Hab and HAL)	
3:15	9:15			Logistics Reconfig (Hab and HAL)	
3:30	9:30	Pre-Exercise Prep and Set-up			
3:45	9:45	Exercise (HAL GRC Ergo)	Exercise (Hab HOPPER)	Lunar Traverse and Sample Collection (HAL)	
4:00	10:00	Exercise (Hab HOPPER)	Exercise (HAL GRC Ergo)		
4:15	10:15	Post-Exercise Clean-up and Reconfig		Sample Return and Habitat Science Airlock Operation (HAL)	
4:30	10:30	Radiation Vest Assessment (HAL)			
4:45	10:45			HRP Science (Muscle Ultrasound) (Hab)	
5:00	11:00				
5:15	11:15	Imagery (HAL and Hab)			
5:30	11:30	IFM - Filter and RCA (HAL)		Personal Health Checkout (HAL)	Personal Health Checkout (HAL)
5:45	11:45			Priv. Med. Conf. (HAL)	Priv. Med. Conf. (HAL)
6:00	12:00	Meal Prep (HAL)			
6:15	12:15	Meal (HAL)			
6:30	12:30				
6:45	12:45	Personal Health Checkout (HAL)	Imagery/Charge Reminder	Housekeeping (HAL and Hab)	
7:00	13:00	Priv. Med. Conf.(HAL)	Personal Health Checkout(HAL)		
7:15	13:15	Mini-DNA (Hab)	Priv. Med. Conf.(HAL)	Pre-Exercise Prep and Set-up	
7:30	13:30		Telescope and Observations (Hab)	Exercise (HAL GRC Ergo)	Exercise (Hab HOPPER)
7:45	13:45			Exercise (Hab HOPPER)	Exercise (HAL GRC Ergo)
8:00	14:00			Post-Exercise Clean-up and Reconfig	
8:15	14:15		HRP Science (Vein Ultrasound Simulation) (Hab or HAL)	VR Task (HAL or Hab)	
8:30	14:30				
8:45	14:45				
9:00	15:00			PAO Event Setup	
9:15	15:15	PAO			
9:30	15:30	DPC			
9:45	15:45	Meal Prep			
10:00	16:00	Meal			
10:15	16:15				
10:30	16:30	Daily Habitation Questionnaires and Metrics Ratings			
10:45	16:45				
11:00	17:00				
11:15	17:15				
11:30	17:30				
11:45	17:45				

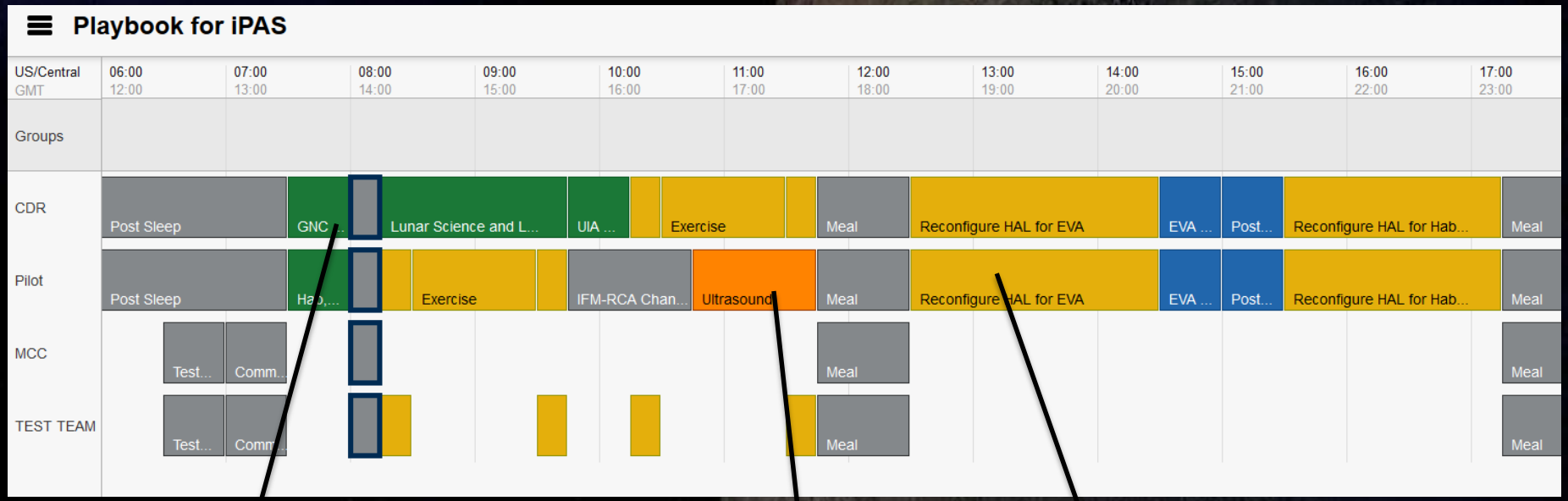
May Test – Engineering Day 3 (Habitat and EVA)

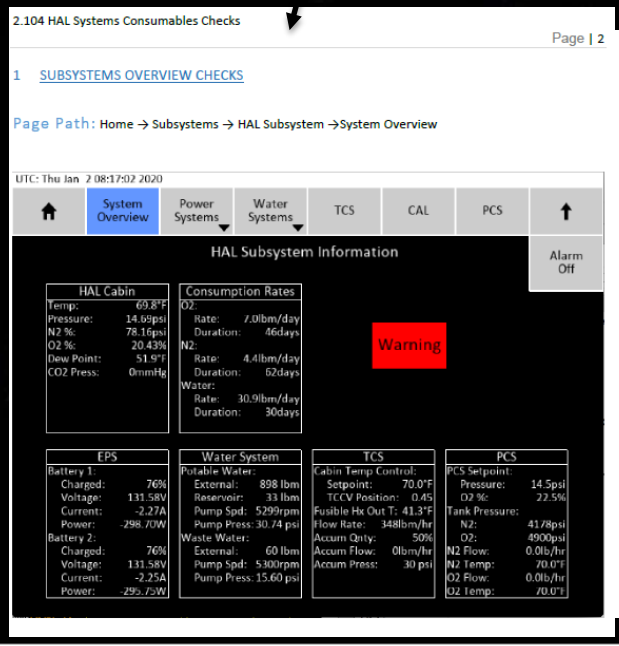
PET	Time of Day	CDR	Pilot	MS 1	MS 2
0:15	6:15	Post-Sleep (HAL) (Hygiene, WCS Ops, Meal Prep, Meal, Prep for DPC)			
0:30	6:30				
0:45	6:45				
1:00	7:00				
1:15	7:15				
1:30	7:30				
1:45	7:45	GNC Checks (HAL) (Nav State, Orbit & Attitude Adjusts)		Hab Systems & Consumables Checks (Hab) (ECLSS, Power, Thermal, Vehicle Health)	
2:00	8:00				
2:15	8:15	DPC (Hab)			
2:30	8:30	Orion Systems & Consumables Checks (Hab)		Reconfigure HAL for EVA	
2:45	8:45	HAL Systems & Consumables Checks (Hab)			
3:00	9:00	Pre-Exercise Prep and Set-up (Hab)			
3:15	9:15	Exercise (Hab)	LLT Rover Sim (Hab)	SCU Install and Checkout	
3:30	9:30				
3:45	9:45			Airlock Prep	
4:00	10:00	Post-Exercise Clean-up (Hab)		Airlock Campout	
4:15	10:15	LLT Robotic Manipulation Sim (Hab)	Exercise (Hab)	EVA Teather Inspection	
4:30	10:30			EVA Tool Config	
4:45	10:45			EVA Prep and Purge	
5:00	11:00		Post-Exercise Clean-up and Reconfig		
5:15	11:15	Trash Management and Housekeeping (Hab)		Crewlock Depress	
5:30	11:30			Crewlock Repress	
5:45	11:45	Meal Prep (Hab)		EVA PostOps	
6:00	12:00	Meal (Hab)		SCU Uninstall	
6:15	12:15			Reconfigure HAL for Habitation	
6:30	12:30	Reconfigure HAL for EVA			
6:45	12:45			Meal Prep (Hab)	
7:00	13:00			Meal (Hab)	
7:15	13:15	SCU Install and Checkout			
7:30	13:30			IFM (Hab)	VR Task (Hab)
7:45	13:45	Airlock Prep			
8:00	14:00	Airlock Campout		Pre-Exercise Prep and Set-up	
8:15	14:15	EVA Teather Inspection		Exercise (Hab)	LLT Rover Sim (Hab)
8:30	14:30	EVA Tool Config			
8:45	14:45	EVA Prep and Purge (include last minute items)			
9:00	15:00			Post-Exercise Clean-up	
9:15	15:15	Crewlock Depress		LLT Robotic Manipulation Sim (Hab)	Exercise (Hab)
9:30	15:30	Crewlock Repress			
9:45	15:45	EVA PostOps			
10:00	16:00	SCU Uninstall			Post-Exercise Clean-up and Reconfig
10:15	16:15	Reconfigure HAL for Habitation		Meal Prep (Hab)	
10:30	16:30				
10:45	16:45	Meal (Hab)			
11:00	17:00				
11:15	17:15	DPC			
11:30	17:30	Crew Consensus Questionnaires			
11:45	17:45				
12:00	18:00				
12:15	18:15				
12:30	18:30				
12:45	18:45				
13:00	19:00				

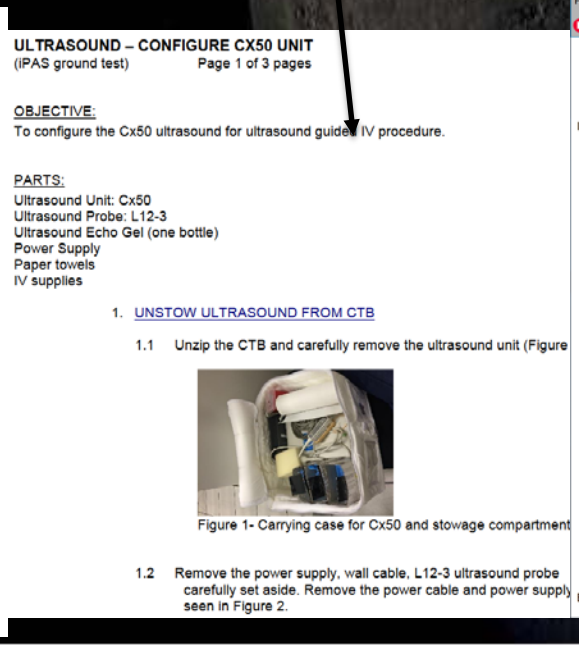
NASA-Developed Procedures and Mission Content Available For Incorporation into Contractor Testing

- **Software Tools**
  - Playbook Timeline Control
  - ProX Procedures
- **Subsystem Simulation Procedures**
  - GNC Systems Checks
  - Hab Systems and Consumables Checks
  - HAL Systems and Consumables Checks
  - Orion Systems and Consumables Checks
- **Exercise**
  - MED2 Installation and General Ops
  - GRC Ergometer Setup and Exercise
  - HOPPER Setup and Exercise
- **Science**
  - Telepresence Lunar Rover Traverse v5
  - Telescope Observations v4
  - MiniDNA Sequencer Procedure
- **EVA**
  - Airlock Prep
  - Airlock Campout Initialization
  - EVA Tether Inspection
  - EVA Tool Config
  - EVA Prep and Purge
  - Airlock Depress
  - Airlock Repress
  - EVA Post Ops
- **Robotics**
  - LLT Rover Simulation Procedures
  - LLT Manipulation Simulation
  - DSG RMS Sample Return Transfer
- **Medical**
  - Medical Contingency Ultrasound guided IV - intravenous access
  - SPRINT Thigh Muscle Ultrasound Assessment
- **In-Flight Maintenance (IFM)**
  - ECLSS Component Replacement

Timeline And Procedure Control Utilizing Playbook







ULTRASOUND – CONFIGURE CX50 UNIT
(iPAS ground test) Page 1 of 3 pages

OBJECTIVE:
To configure the Cx50 ultrasound for ultrasound guided IV procedure.

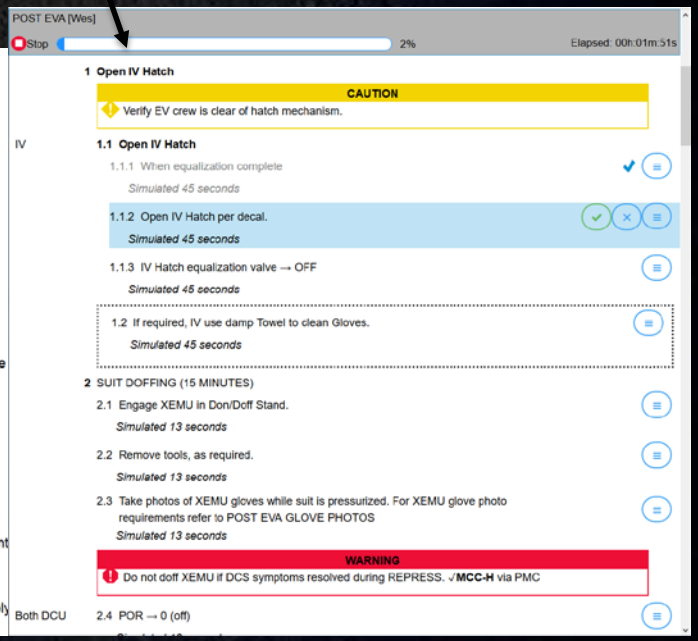
PARTS:
Ultrasound Unit: Cx50
Ultrasound Probe: L12-3
Ultrasound Echo Gel (one bottle)
Power Supply
Paper towels
IV supplies

1. UNSTOW ULTRASOUND FROM CTB

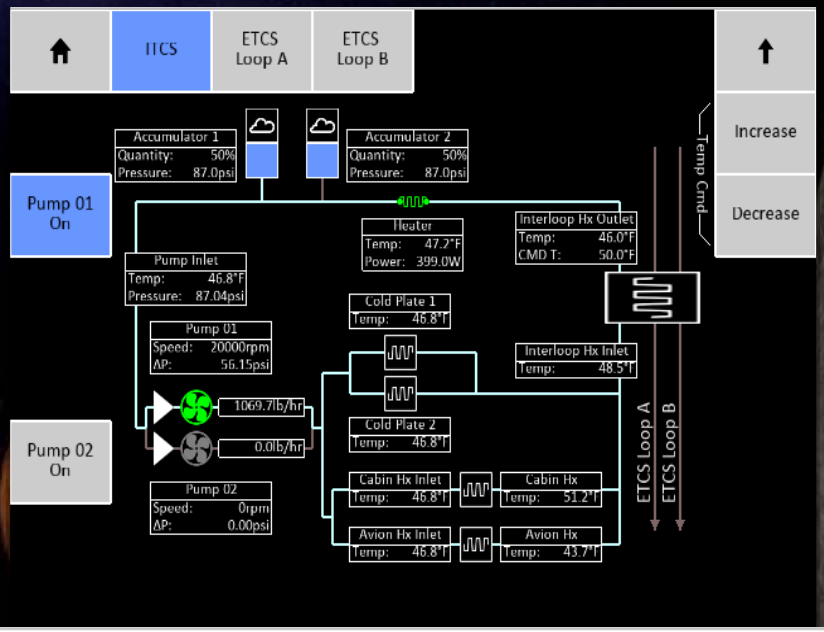
1.1 Unzip the CTB and carefully remove the ultrasound unit (Figure

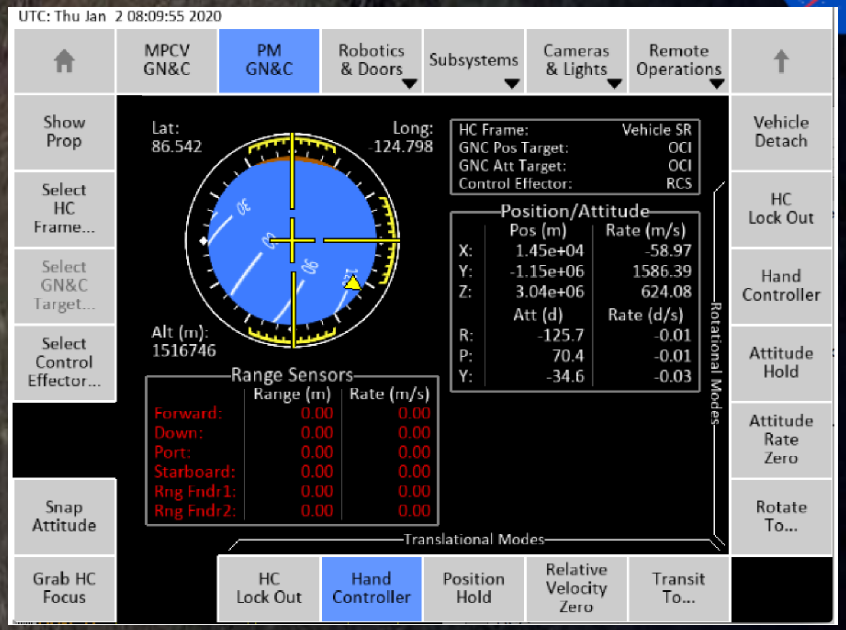
Figure 1- Carrying case for Cx50 and stowage compartment

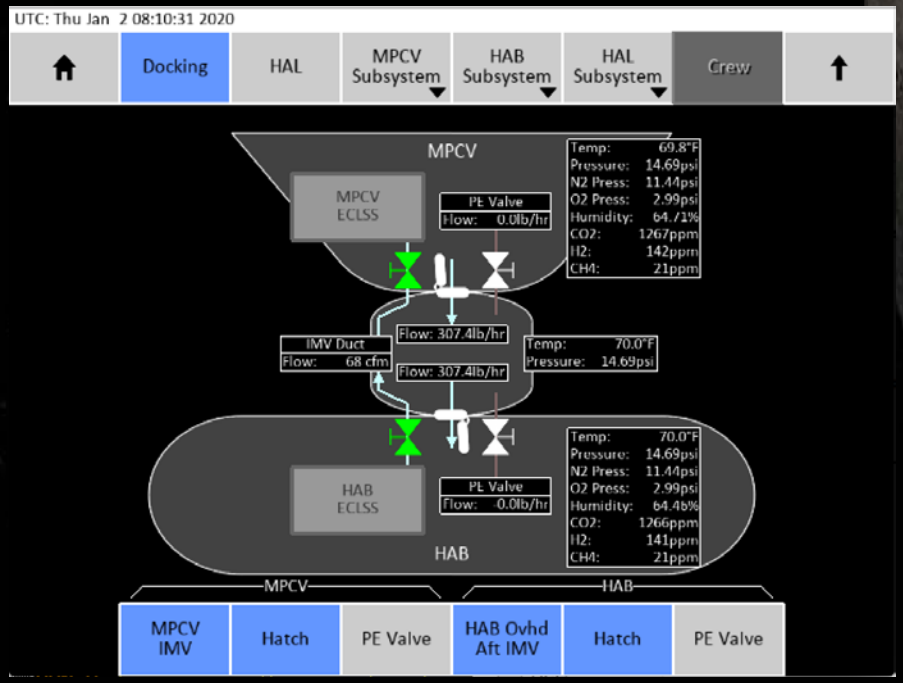
1.2 Remove the power supply, wall cable, L12-3 ultrasound probe carefully set aside. Remove the power cable and power supply seen in Figure 2.

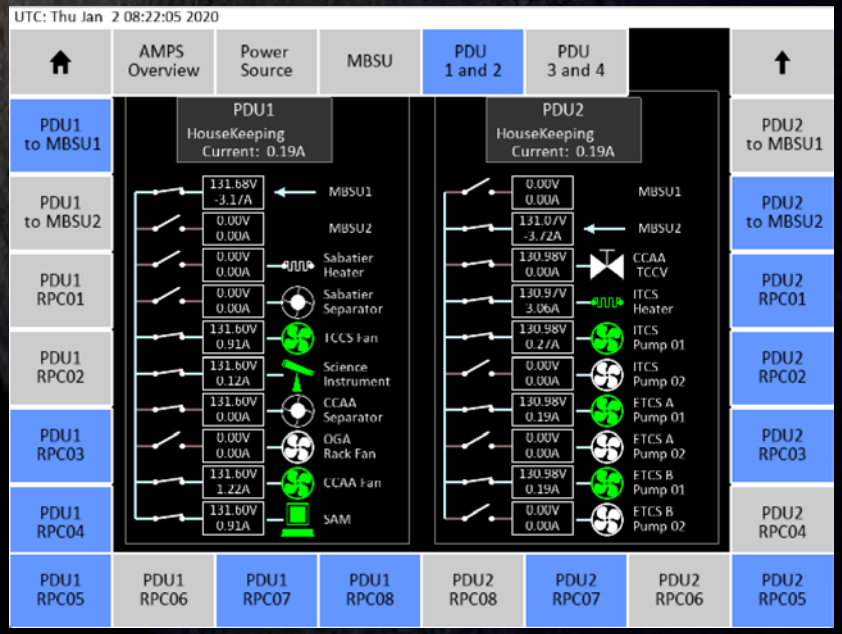


High Fidelity Subsystem Models of HAL and Hab Systems

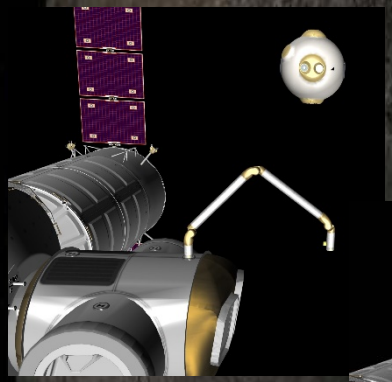


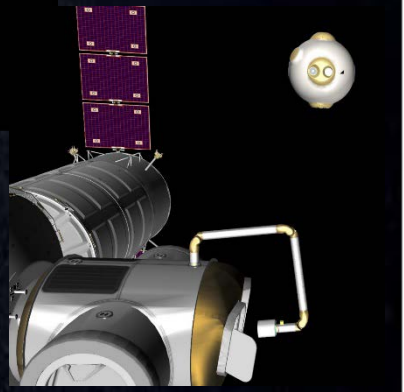






LLT Rover and Robotic Sample Return Simulations





TASK DESCRIPTIONS AND OBJECTIVES

Big Picture

- **This test configuration represents the assembly complete of the Gateway.**

- **This test includes a habitat and a multifunction airlock. Although not mocked up the Orion and at least one logistics module will be part of the stack.**

- **The mission timeline was developed to exercise all functional requirements of the gateway and we hope represents a realistic set of tasks with a flight-like ops tempo, communications, and procedures.**

- **As a subject evaluator you should take the point of view that you are an astronaut that will be utilizing this gateway for 30 day missions in the future.**
  - This is your opportunity to provide inputs into the design features and capabilities that you like and don't like.
  - Keep in mind the gateway is time and budget constrained and only the first step toward future lunar and Mars missions.
    - This is not the Deep Space Transport system or a long mission duration space station.

- **The goal of this evaluation is to evaluate the design and layout of the habitation system. It is not to evaluate the task that you are doing.**
  - At the end of the mission we will ask you to evaluate the fidelity and quality of the tasks so we can improve the tasks for subsequent tests if warranted.
  - **Please do not conflate a good or bad task with a good or bad habitation design/ layout**

Limitations

The ground test and analysis protocol for the DSG has a number of limitations, including, but not limited to:

♦ Number, Type, and Fidelity of DSG Contractor Mockups:

- Due to budget, schedule, and 1-g limitations the NextSTEP BAA testing will not include mockups of the Orion or logistics module. The contributions of Orion and the logistics module will be assessed through a combination of analyses, VR, and standalone testing rather than fully integrated HITL testing. The fidelity of DSG contractor habitation and EVA modules could vary widely, and for this reason, our simulation quality scale will be used to discriminate which data will be used for tests of the hypotheses and forward DSG recommendations.

♦ 1-g Test Environment:

- The DSG will be implemented in micro-gravity which is not possible to fully simulate in 1-g environment. However previous testing has shown that 1-g mockups which contain features required for microgravity operations (e.g. handholds, foot loops, Velcro, etc.) combined with the expertise of experienced astronauts can result in meaningful assessments. VR can also be used to address some aspects of microgravity, such as full utilization of the habitation volume (e.g. exercise on ceiling versus floor) which would not be possible in a 1-g test.

♦ HITL Study Design:

- The NextSTEP BAA will result in five different habitation configurations. At this time, the details of each individual DSG contractor configuration with respect to the number and type of modules and distribution of habitation, science, and EVA functions, are not known. Also, since each contractor will provide their own designs, we do not have the control to systematically vary the independent and dependent variables. For this reason, multiple specific hypotheses could not be prospectively developed. Instead, two high-level hypotheses are proposed that provide the framework to guide the HITL testing and evaluation. The results of the HITL testing across all five configurations will be assimilated, analyzed, and used to inform future requirements and design recommendations for the DSG. In this type of HITL testing (using the targeted population of astronauts as test subjects), it is not possible to execute the studies with large numbers of subjects (e.g. limited number of astronauts, scheduling constraints). Therefore, although individual data will be collected, the crew's consensus evaluation will be used to test the hypotheses and to identify the actionable results.

Flight Rules

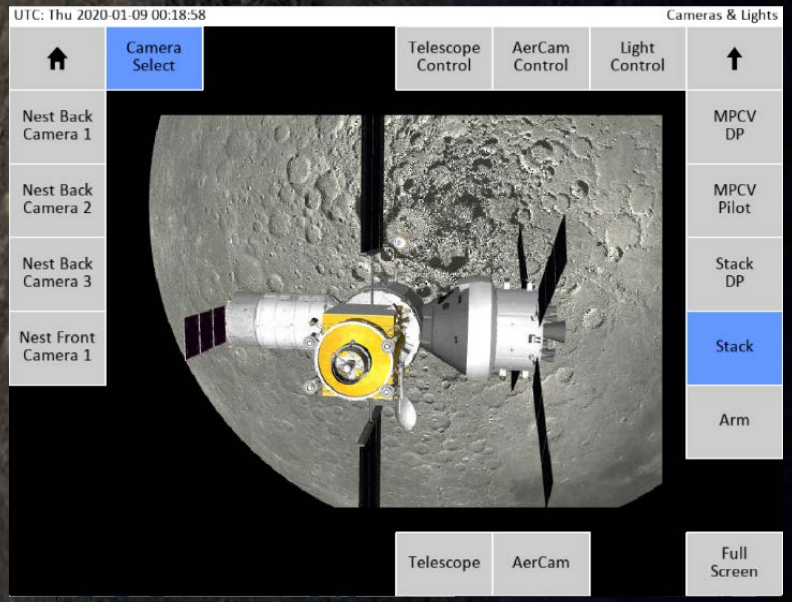
- **Space-to-ground communication troubleshooting:** Communication team can spend up to 5 min troubleshooting communication network. After 5 mins, all space-to-ground communication will be relayed through open hatch doors until communication is restored; if communication between B30 MCC and B29 Test Support is functioning operate in single person bent pipe mode through B29 Sim Sup until such time as communication is restored.
  - If B30 MCC <> B29 Test Support communication goes down, B30 CapCom calls crew cell phone inside Hab/Hal (CapCom will call whichever pair they were working with when comm went down) and MCC continues from B30.
  - If communication between MCC and B29 is disconnected for more than 30 min, MCC/SME talks to B29 Capcom via cell phone (bent pipe mode).

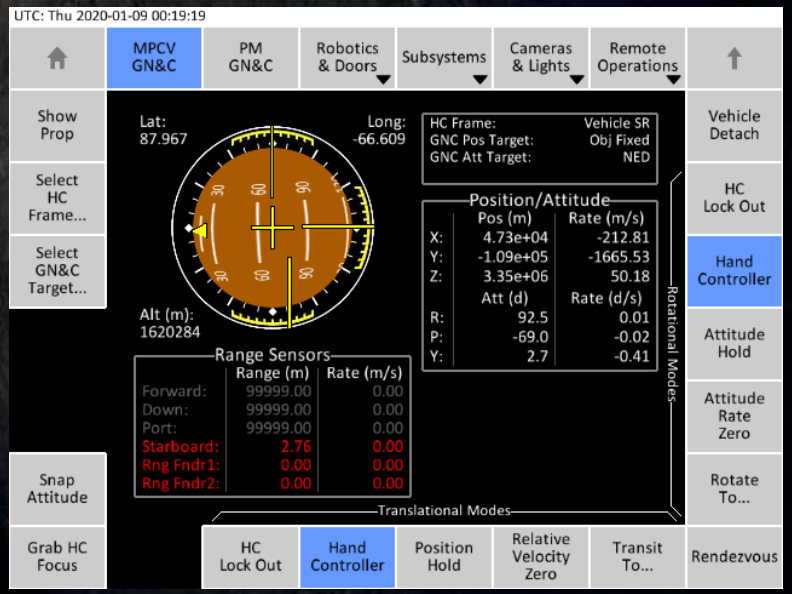
- **Physical hardware troubleshooting:** Up to two individuals can enter vehicle to conduct troubleshooting for up to two hours. If there is a complete hardware failure that takes more than 5 min to resolve the crew should move to the next timeline task that doesn't involve that hardware, or as instructed by MCC.

- **Simulation troubleshooting:** Simulation team can spend up to 5 min troubleshooting. If simulation cannot be fixed in 5 min and timeline allows, crew will move to the next simulation on their timeline. If no simulations are working, crew will move the next functioning timeline task. If crew begins a new timeline task and they are less than 10 min in when the original simulation task is recovered, they should switch back to the original simulation task; if they are more than 10 min in to the new task, they should finish the new task.

GNC Checks and Attitude Adjustments

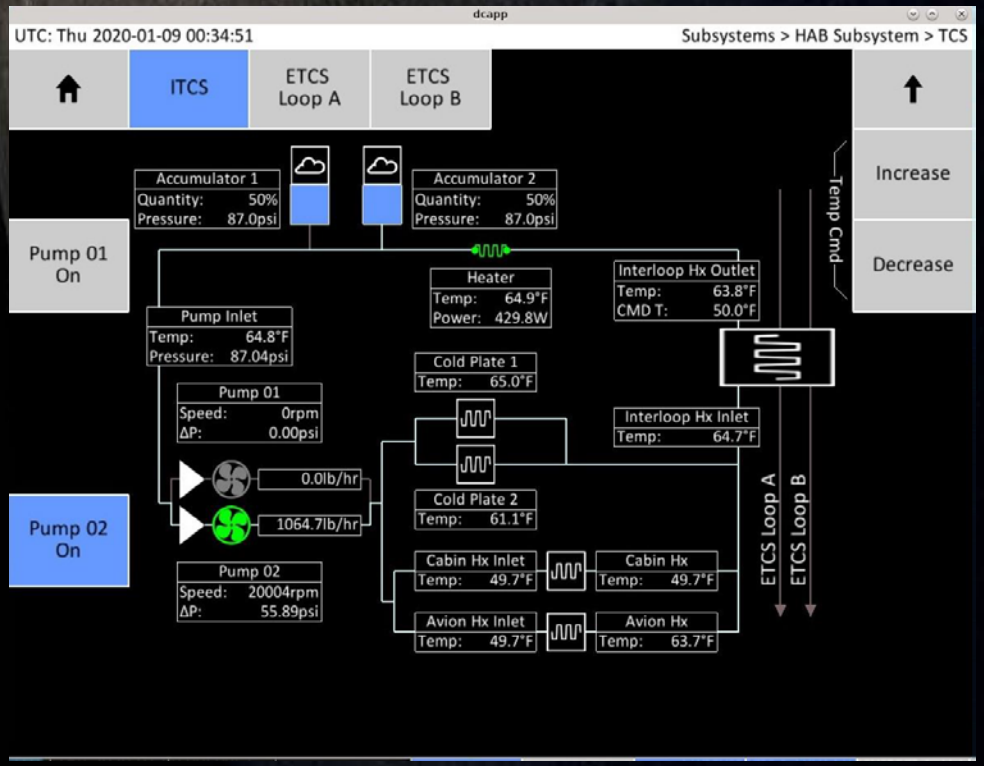
- **Task Description**
  - This is a simple task to check prop quantities on the PPM and the Orion, check and verify the nav state, input targets and initiate a maneuver to a new attitude for observations later in the day.
  - When you complete this task you be asked to evaluate the multipurpose workstation usability for this task.





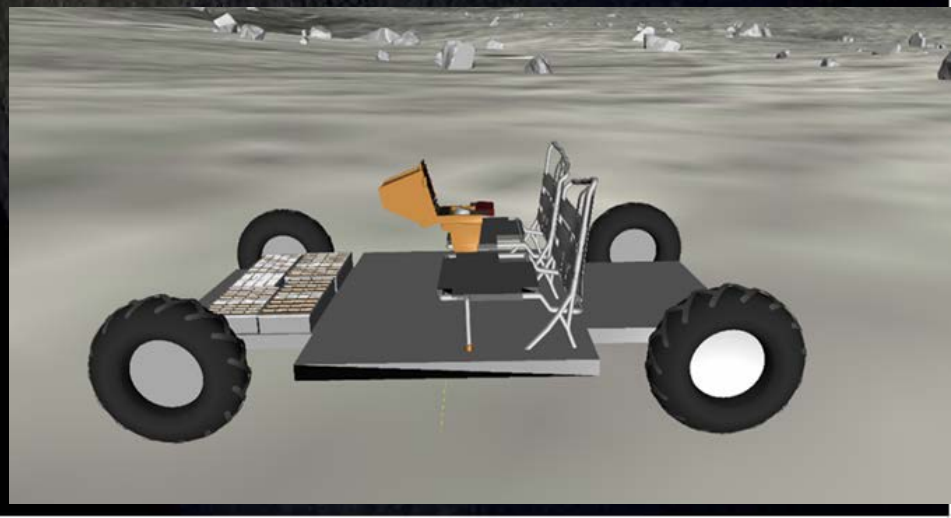
Habitat and Orion Consumables Checks

- **Task Description**
  - Simple task to look at the current consumables quantities (e.g. O2, N2, H2O) for the habitat and Orion, and perform a pump swap activity
  - Evaluate the multipurpose workstation layout and design for this task.



LLT Lunar Rover Simulation

- **Task Description**
  - This task involves driving a lunar rover through a congested rock field with the goal of reaching a sample return ascent vehicle.
  - There are multiple randomized runs with different latency times (this is for data collection to look at LLT rover operations)
  - The simulation has a high fidelity physics rover and contact model and you can run over or get stuck on rocks.
    - If you get stuck on a rock end the run and start the next one
  - When complete you will be asked to evaluate the layout of the multipurpose workstation and hand controller for performing this task.

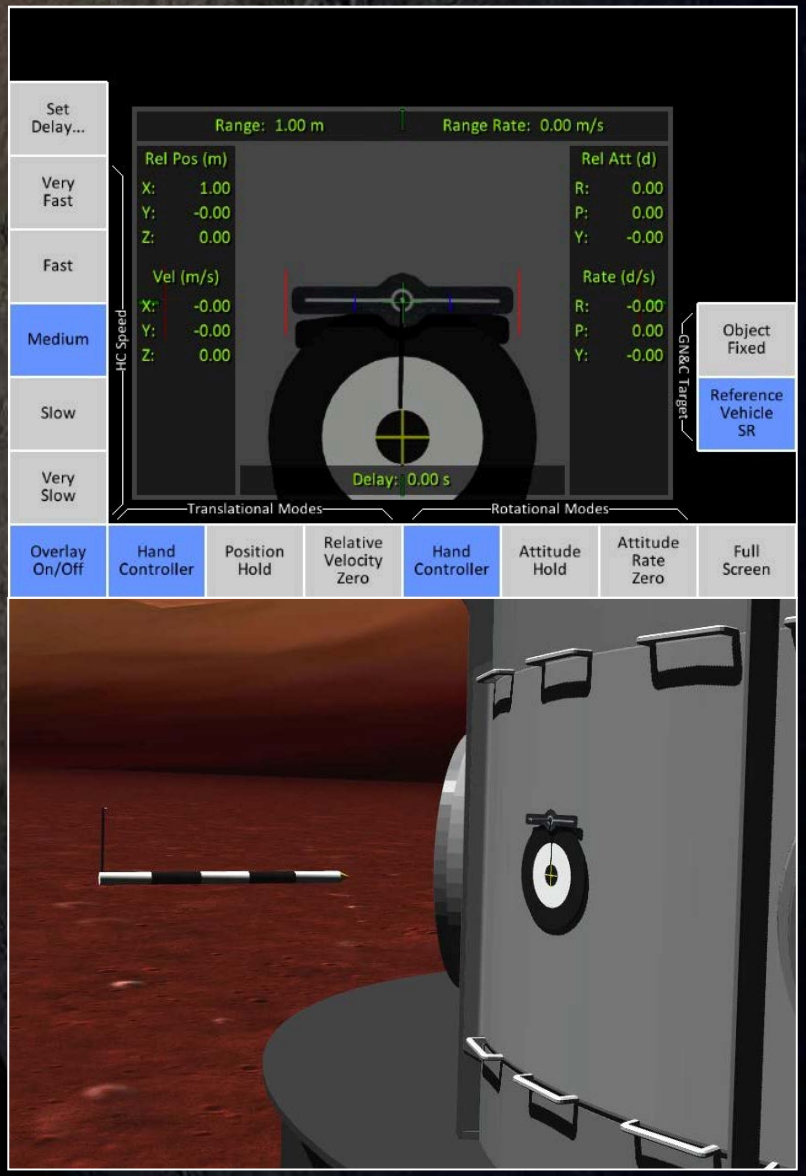


Lunar Traverse and Sample Collection Simulation

- **Task Description**
  - Similar task to the Lunar Rover however two crew work together using a map to locate targeted rocks marked with a blue or green dot in a boulder field
  - When complete crew will be asked to evaluate the location, usability, and layout of the multipurpose workstation for two person robotics operations.

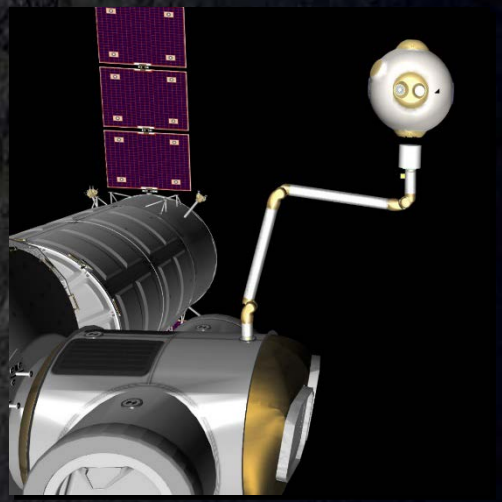
LLT Manipulation Simulation

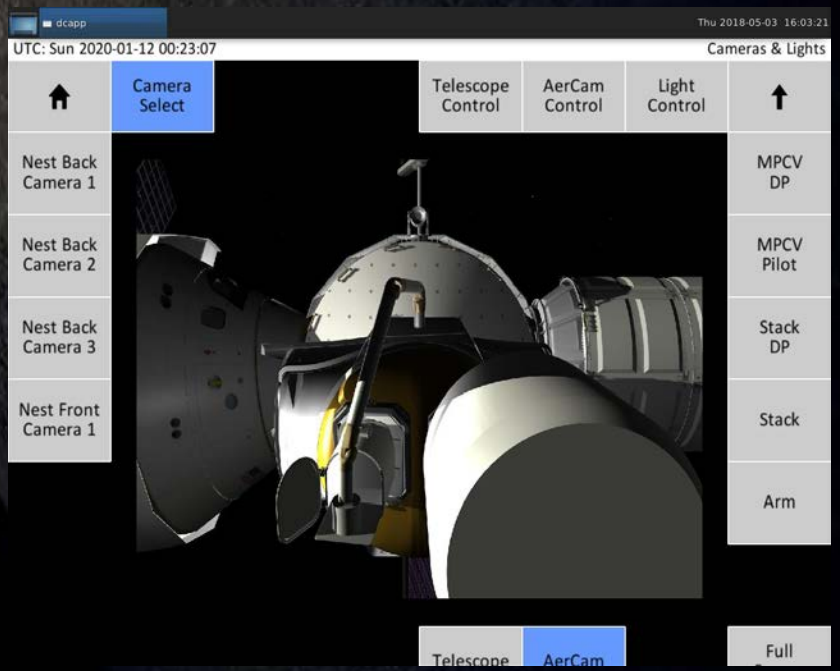
- **Task Description**
  - This task is a standalone study to evaluate human teleoperation rotational and translational accuracy as an input to the design of future low latency tele-robots and tasks.
  - The latency times range from 0, 250ms, 500ms, 750ms, and 1s
  - In the context of this mission you can think of this as manipulation to place a rock sample on the sample return spacecraft.
  - When complete you will be asked to evaluate the multipurpose workstation and hand controller for performing this task.



Sample Return RMS Ops Simulation

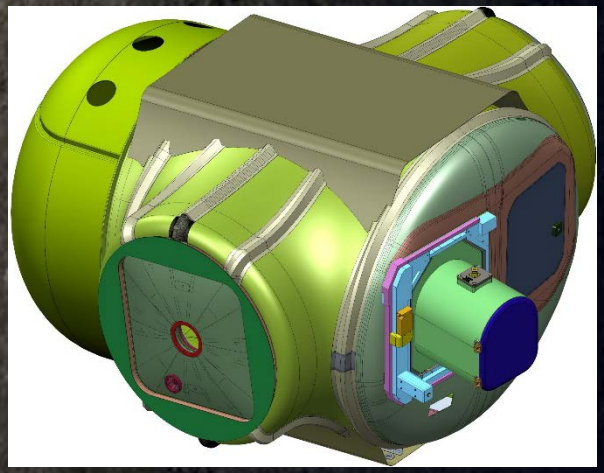
- **Task Description**
  - This task involves magnetically grappling a sample return spacecraft with a ferrous plate on the sample return canister.
  - The space craft is then commanded to release the canister and the RMS is then used to position the canister in a science airlock secondary containment vessel.
  - The procedure involves operating both the RMS and the science airlock and results in the sample being brought inside the spacecraft.
  - Evaluate the location, layout, and usability of the multipurpose workstation in this habitation element layout for performing this task.





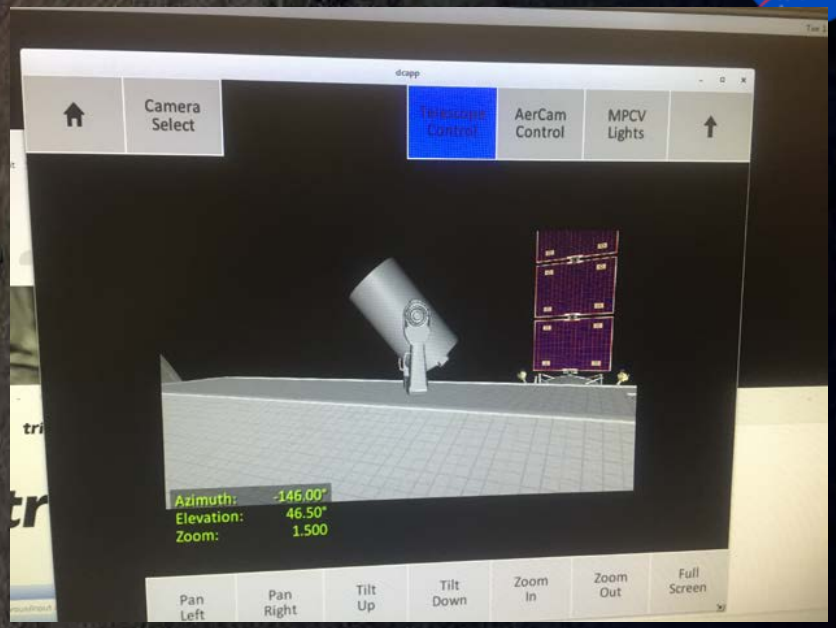
Science Glove Box / HAL Science Airlock

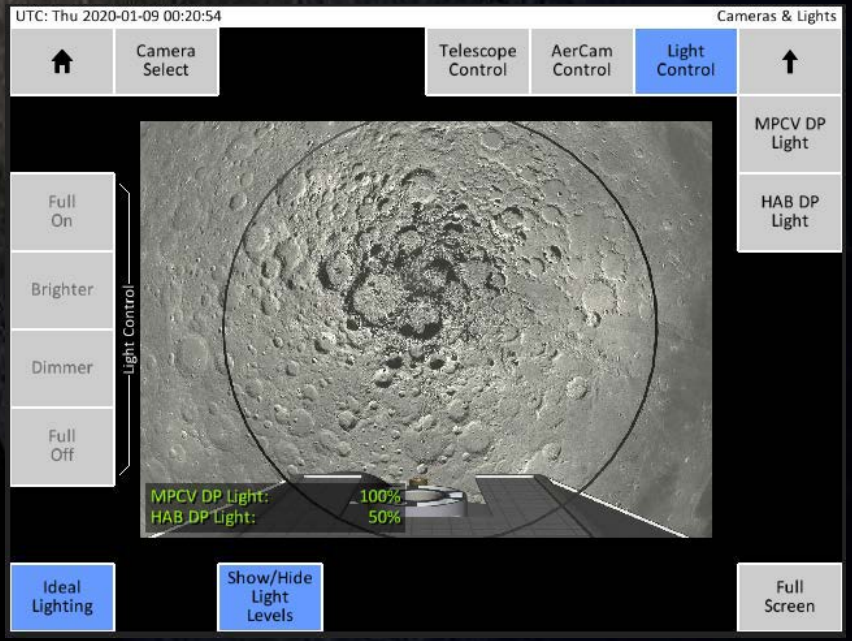
- **Task Description**
  - This is a very simple task that involves either 1) opening the HAL science airlock and bringing in the secondary containment vessel and simulating taking it to the Orion. Or 2) the sample will magically appear in the habitat and you will place it in the glove box and manually put it in a secondary containment vessel.
  - Habitat - Evaluate the location and volume necessary to perform glove box science in this habitation layout.
  - HAL – Evaluate the location, design, and capability enhancement of the HAL Science Airlock.



Telescope Observations

- **Task Description**
  - This procedure is currently under revision but today you will get the big picture skills.
  - Basically involves pointing the telescope at targets on the earth, moon, and sun and taking pictures.
  - Evaluate the multipurpose workstation for performing this task in both the habitat and the HAL.

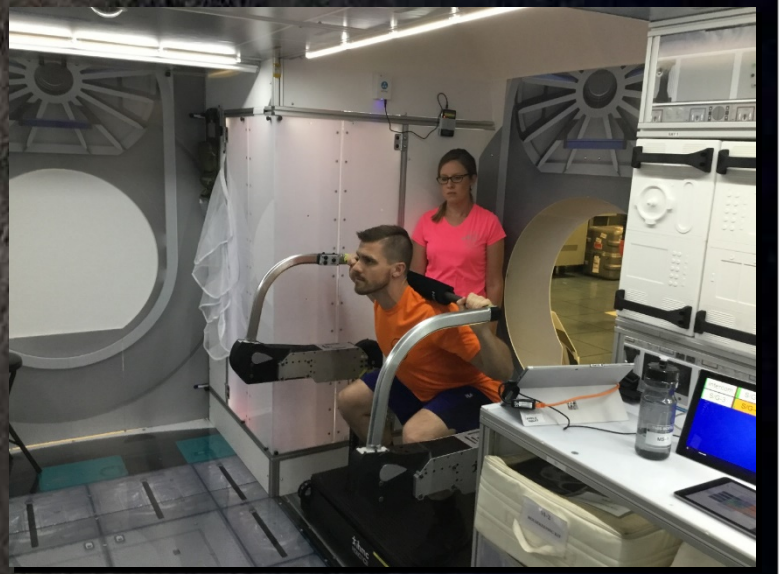




Exercise – Hopper and GRC Ergometer

♦ **Task Description**

- Hopper: Perform exercise using the Hopper, a representative resistive exercise device.
  - Task involves setting up the device, exercising and stowing
- Note:
  - Exercise equipment for this test is a prototype device and does not include all the planned capabilities for a Gateway device (e.g. rowing); however the equipment has been put into place for operational volume assessments.

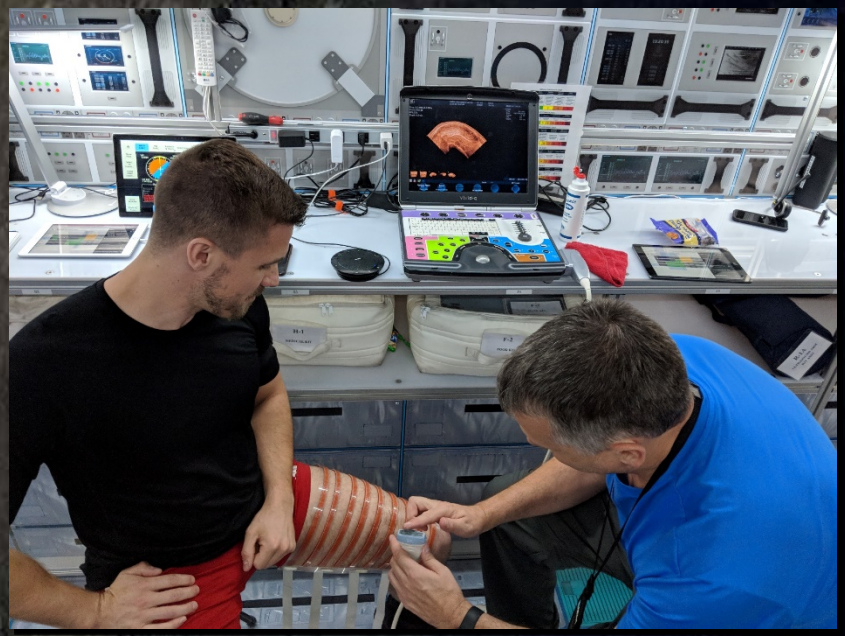


- GRC Ergometer: Task involves setting up a small combination ergometer and resistive exercise device in the HAL. Performing exercise and breaking down and stowing the device.

- You will be asked to evaluate the acceptability of the location, exercise volume, noise levels, setup, breakdown, and any interferences of exercise with the other crewmembers.

Ultrasound – Muscle

- **Task Description**
  - This is a simple task that involves setting up an ultrasound machine following a procedure. Once set up the ground will talk you through performing a guided ultrasound scan of the leg muscles using a colored and number coded keypad.
  - This procedure is a reduced version of the flight procedure completed by crew onboard ISS during the S.P.R.I.N.T Study however the fidelity is nearly identical to that performed in flight.
    - NO ULTRASOUND OR MEDICAL DATA IS COLLECTED DURING THIS PROCEDURE EVALUATION!
  - Evaluate the layout, associated volume, privacy, and interference associated while performing such exams.

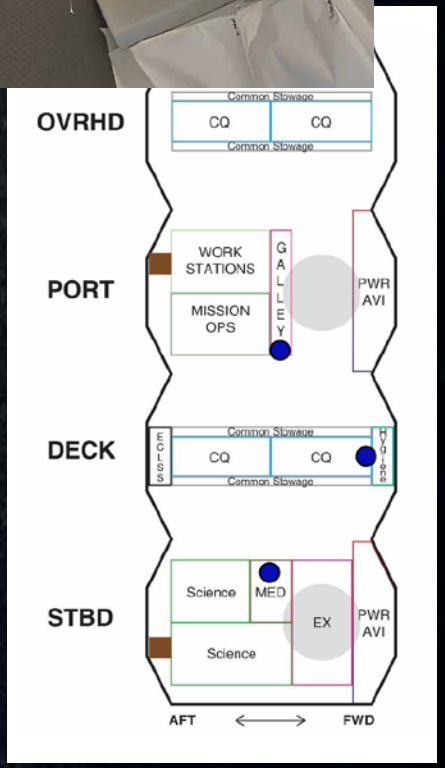


Ultrasound – Guided IV Catheter Simulator

- **Task Description**
  - This task involves inserting an IV into the vein of an arm phantom using ultrasound to guide the insertion.
  - Assess the associated volume and surfaces necessary to perform the task including temp stowage, restraint locations, and any task interferences with other crewmembers.
  - Arm phantom used in this task should be placed to reflect the total volume an actual crewmember would require.

Habitation Tasks – Galley, Hygiene, Housekeeping

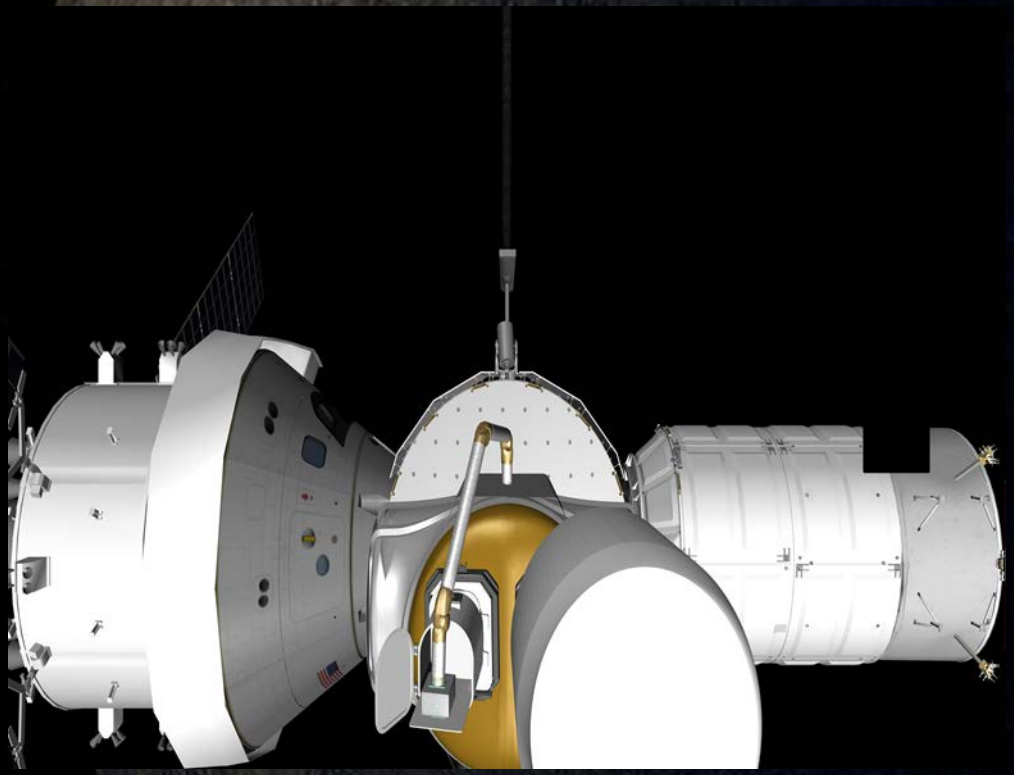
- **Task Descriptions:**
  - Perform basic habitation tasks including housekeeping, meal prep, WCS Ops, hygiene, trash management, sleep prep and post.
  - Also a PAO event will be staged.
  - Crew will move through cabin and perform these routine habitation functions to understand vehicle volume, layout, and any resulting task interferences that may exist.



	Symbol	Item to be Cleaned	Instructions
7.	●	SDS Sample Probe	Vacuum, notify **MCC-H** if blockage observed.
8.	▬	Bacteria Filters	Notify **MCC-H** to deactivate Area Smoke Detectors before cleaning. Vacuum Bacteria Filters and surface clean Area Smoke Detectors. Notify **MCC-H** ready for Area Smoke Detector activation.
9.	⊗	Area Smoke Detectors	
10.	■	IMV Grilles ●	Vacuum, disinfect.
11.	●	TCCS Inlet ●	Without opening rack door, clean, disinfect.
12.	▬	Supply Diffusers ●	Vacuum, disinfect.
13.		Ku-Band Power Supply	Inspect and clean vents as required.

Trash Management

- Basic task where crew gathers up temp stow, wet, dry trash from around the cabin and collects into a trash CTB.
- Trash is then ejected from the science airlock using a simulation procedure.
- Crew will assess location and accessibility of trash stowage and evaluate the science airlock for trash ejection.

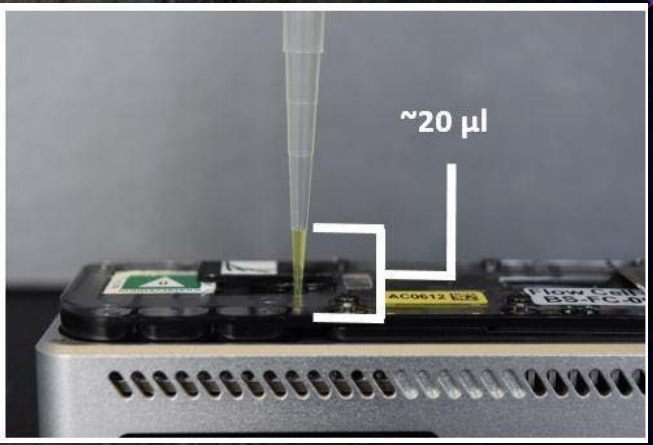


Personal Health Checks and PMCs

- **Task Descriptions**
  - Crewmembers will perform a basic health status assessment measuring temperature, Pulse Oximetry, BP, and HR. Followed by a PMC with a flight surgeon.
  - Crewmembers will evaluate the ability of the habitation element layout and design to provide private areas for personal use. This includes assessments of design features to enable privacy (e.g. curtains).

Mini-DNA Sequencer

- **Task Description**
  - This is a long and complicated task that is representative science currently being performed on space station to collect environmental samples, extract bacterial DNA the MiniDNA Sequencer device.
  - Execute a representative long duration science task requiring a stationary workstation. Examine the volume necessary to complete the task, work surface layout, and potential interference with other crewmembers performing separate activities.



Radiation Vest Assessment

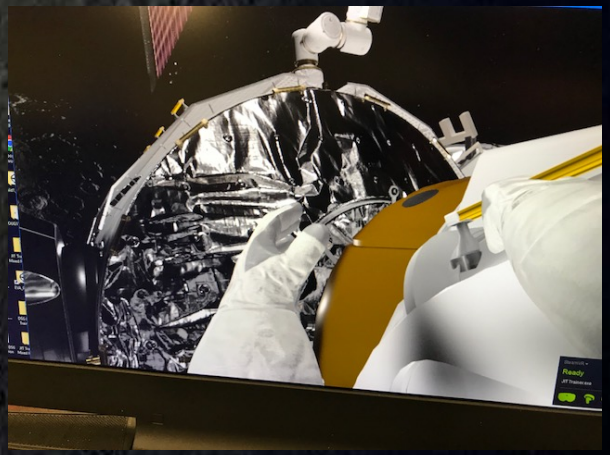
- **Task Description**
  - The radiation vest is prototype personal protective equipment designed at NASA LARC for protection of crew from SPE and other radiation events.
  - Crew will don the vest to determine whether the radiation vest will hinder basic movement and task performance during a critical radiation event.
  - Crewmembers will evaluate the volume and stowage accessibility necessary to quickly access and don the protective equipment.

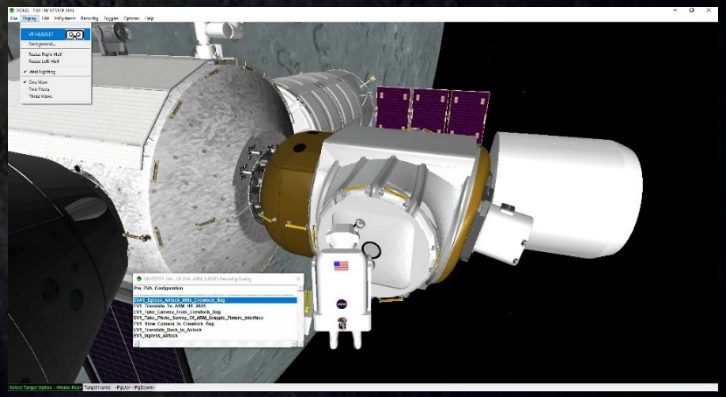
IFM

- **Task Description**
  - Crewmembers will perform three separate IFM tasks that include 1) changing out an MBSU card and a science pallet in the habitat ; 2) replacement of a filter on the UIA panel in the HAL; 3) replacing an RCA swing bed with a spare in the HAL
  - Tasks involve steps for power down as well as the actual IFM itself using 3D printed components
  - Evaluate the acceptability of the layout of the habitat or HAL for access to the failed components and execution of the IFM.
  - Taking into account the location, volume, restraints, and temp stowage available to perform repairs.

Virtual Reality Training for EVA

- **Task Description**
  - Crew will set up a VR headset, hand controllers, and laptop to perform a virtual walk around the DSG stack to train for an upcoming EVA.
  - The VR simulation will provide a helmet and god's eye view
  - Crewmembers will evaluate the volume and location necessary to perform this type of VR training and also comment on crewmember interferences.





EVA Prep and Post

♦ Task Description

- This task will move crew through a full day of EVA preparation and post-EVA activities.
- Crewmembers will configure the HAL to act as an airlock, simulate preparation of two EVA suits, followed by reconfiguration of the HAL as a habitation element.
- Crewmembers will evaluate the volume and layout of the HAL as a multifunction airlock for performing EVA prep and post activities.
- Crewmembers are asked to consider volume and locations to route umbilicals, access to EVA tools and equipment, and stowage locations and methods.
- Crewmembers are asked to consider 0g constraints related to don/doffing, temp stowage locations for tools and equipment, and volume necessary for access to the HAL PRS and logistics.

METRICS AND QUESTIONNAIRES

Metrics

Simulation Quality

Scale Rating	Criteria
1	Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data.
2	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test data.
3	Simulation quality was adequate to provide a meaningful evaluation of most of the test objectives; simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe).
4	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe).
5	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe).

- **Conditions in which simulation quality was rated by test subjects as 4 or 5 would not be included in hypothesis testing.**

Metrics

- **Ratings made by consensus of all test subjects.**
- **<u>A categorical difference in consensus ratings for each rating scale was prospectively defined as being practically significant for the purposes of hypothesis testing</u>**

Acceptability

Categorical Difference

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable	
No improvements necessary		Minor improvements desired		Improvements warranted		Improvements required		Major improvements required	
1	2	3	4	5	6	7	8	9	10

No Categorical Difference

Capability Assessment

Categorical Difference

Essential/Enabling		Significantly Enhancing		Moderately Enhancing		Marginally Enhancing		Little or No Enhancement	
Impossible or highly inadvisable to perform mission without capability		Capabilities are likely to significantly enhance one or more aspects of the mission		Capabilities likely to moderately enhance one or more aspects of the mission or significantly enhance the mission on rare occasions		Capabilities are only marginally useful or useful only on very rate occasions		Capabilities are not useful under any reasonable foreseeable circumstances	
1	2	3	4	5	6	7	8	9	10

No Categorical Difference

Crew Performance Metrics (Collected Morning, Noon, and Night)

- **Workload Ratings**
  - Crewmembers ability to maintain maximum possible task performance in a given environment, test condition, task overlap or interference from other crewmembers performing their own tasks.
  - While this does not directly provide insight into the distribution of functions across the DSG configuration it does provide data into task and overall habitation system design. For example, workload may be rated high during setup of exercise equipment if the vehicle interfaces, accessibility, and procedures are complex.

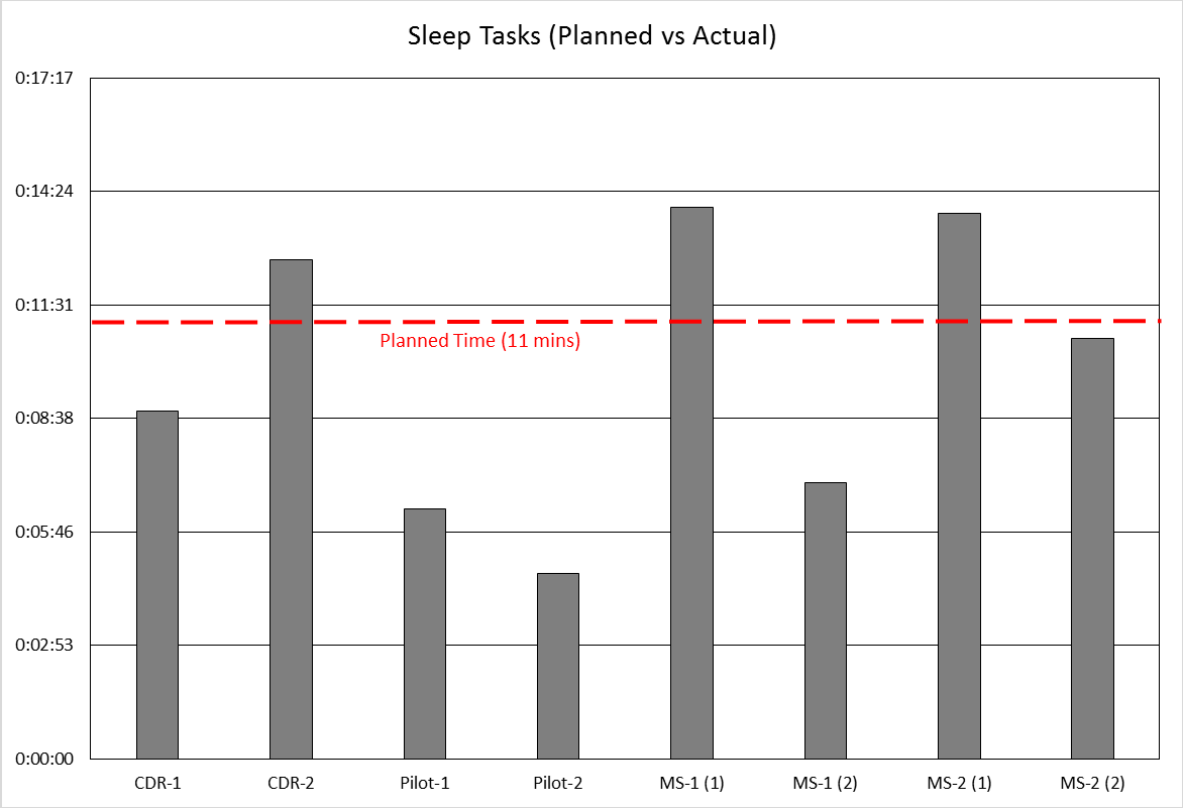
Insignificant Workload		Light Workload		Moderate Workload		Significant Workload		Maximum Workload	
Insignificant mental effort – Significant spare capacity remaining		Light mental effort – Desirable spare capacity remaining		Moderate mental effort – Enough spare capacity remaining		Significant mental effort – Very little spare capacity remaining		Maximum mental effort – No space capacity remaining	
1	2	3	4	5	6	7	8	9	10

- **Fatigue Ratings**

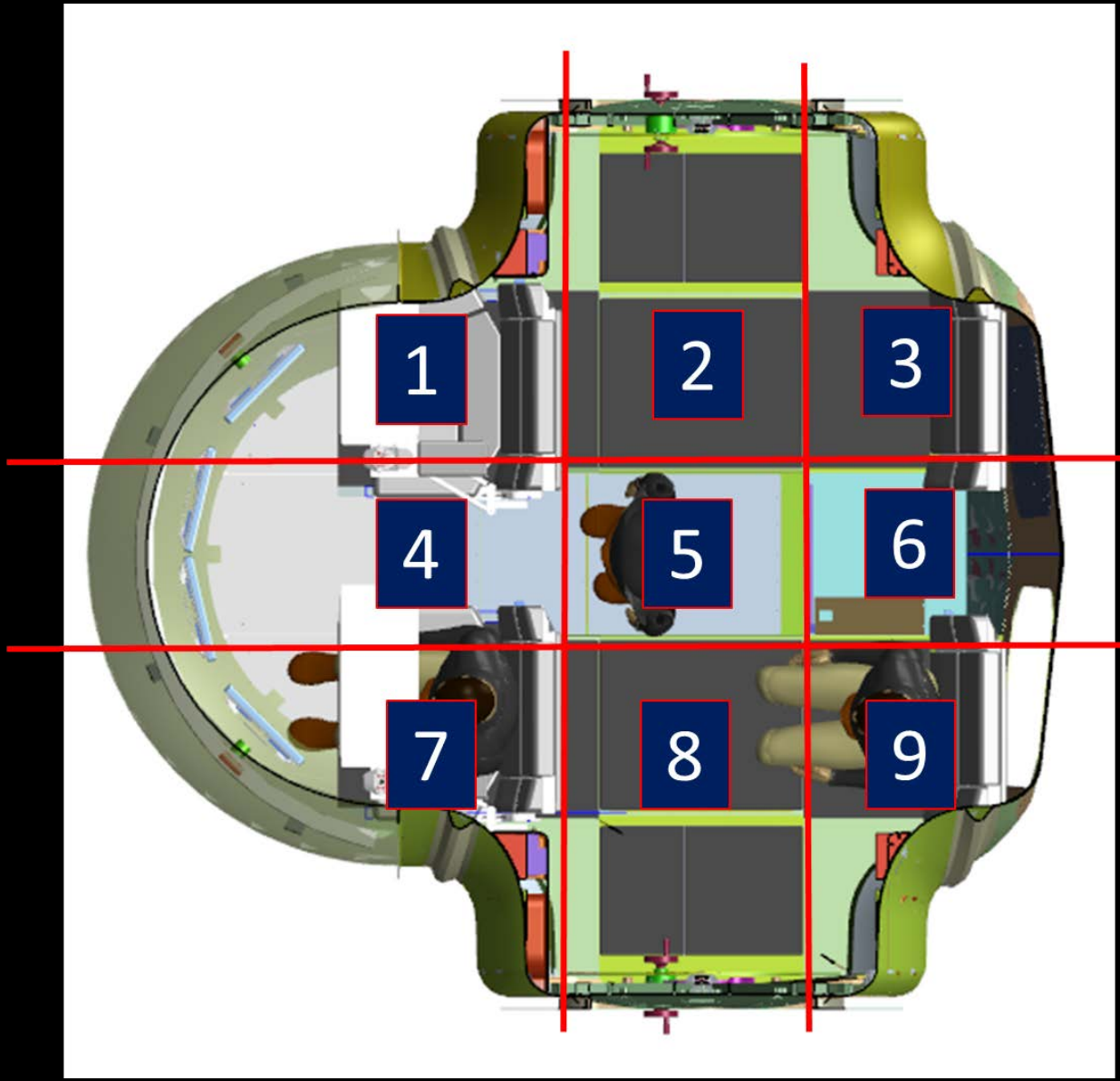
No Fatigue		Minor Fatigue		Moderate Fatigue		Significant Fatigue		Extreme Fatigue	
No Fatigue – performance not compromised		Minor Fatigue – performance not compromised		Moderate Fatigue – performance will likely be compromised if continued		Significant Fatigue – performance is compromised		Extreme Fatigue – unable to continue with adequate performance	
1	2	3	4	5	6	7	8	9	10

Crew Performance Metrics

- **Planned versus Actual Timeline Execution**
  - Overall timeline and individual task durations will be collected and compared to the planned times to provide contextual understanding of other crew performance metrics.
  - The actual time to perform tasks on the mission timeline will be compared to the planned times and the results will be presented along with insight as to what may have caused the differences, such as conflicts for use of the same habitable volume, simulation quality effects, crew training for test, etc.
  - Additionally, crewmember wait times and number of interrupts will be considered to evaluate DSG function layout.

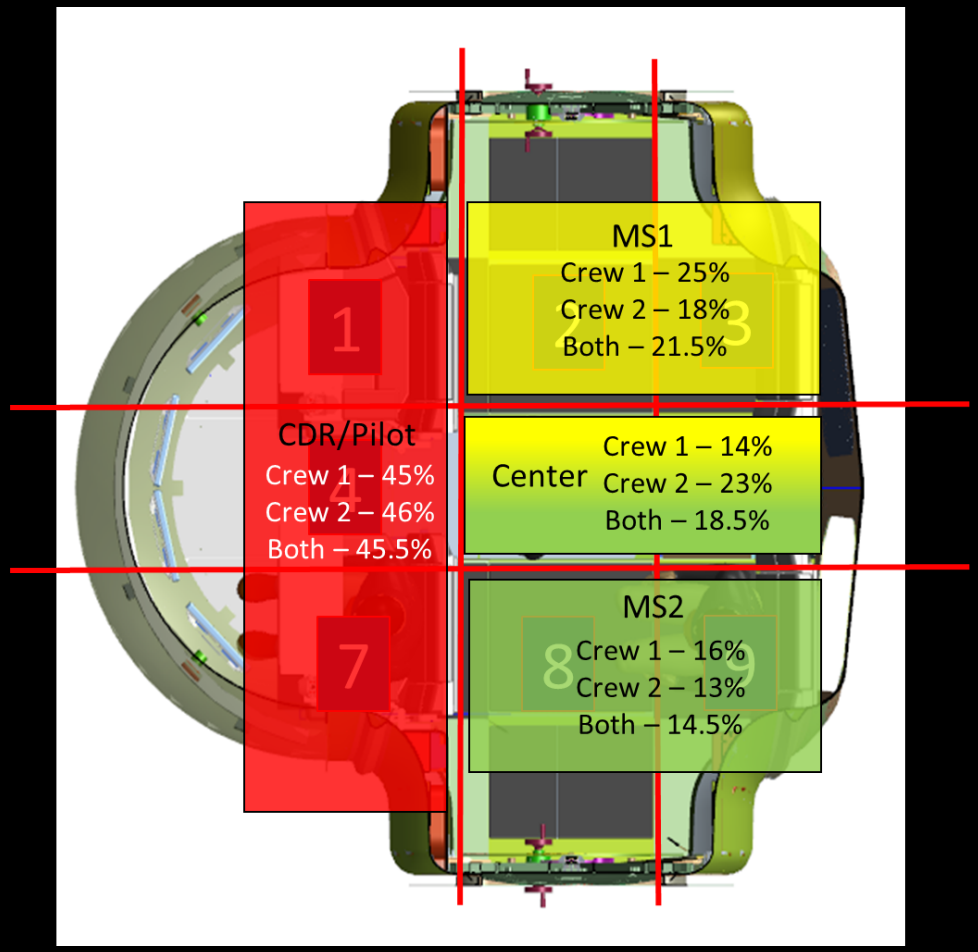


Example of Zone Definition



Crew Time Frequency Map Results

MAV Sectional Heat Map in Percentage



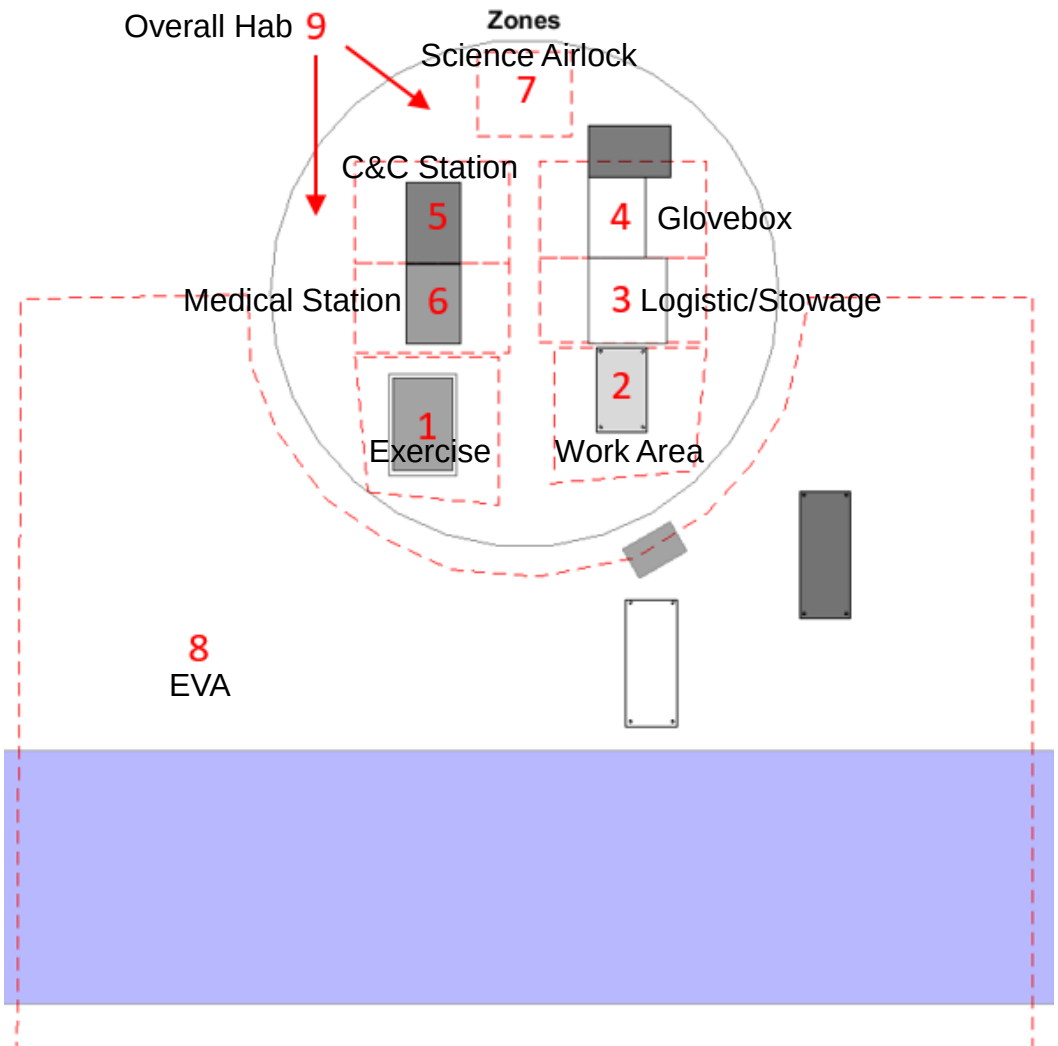
Frequency of time spent in each area consisted of actual task completion times and task discussion

Total Time = 819 minutes

ALLTRAQ

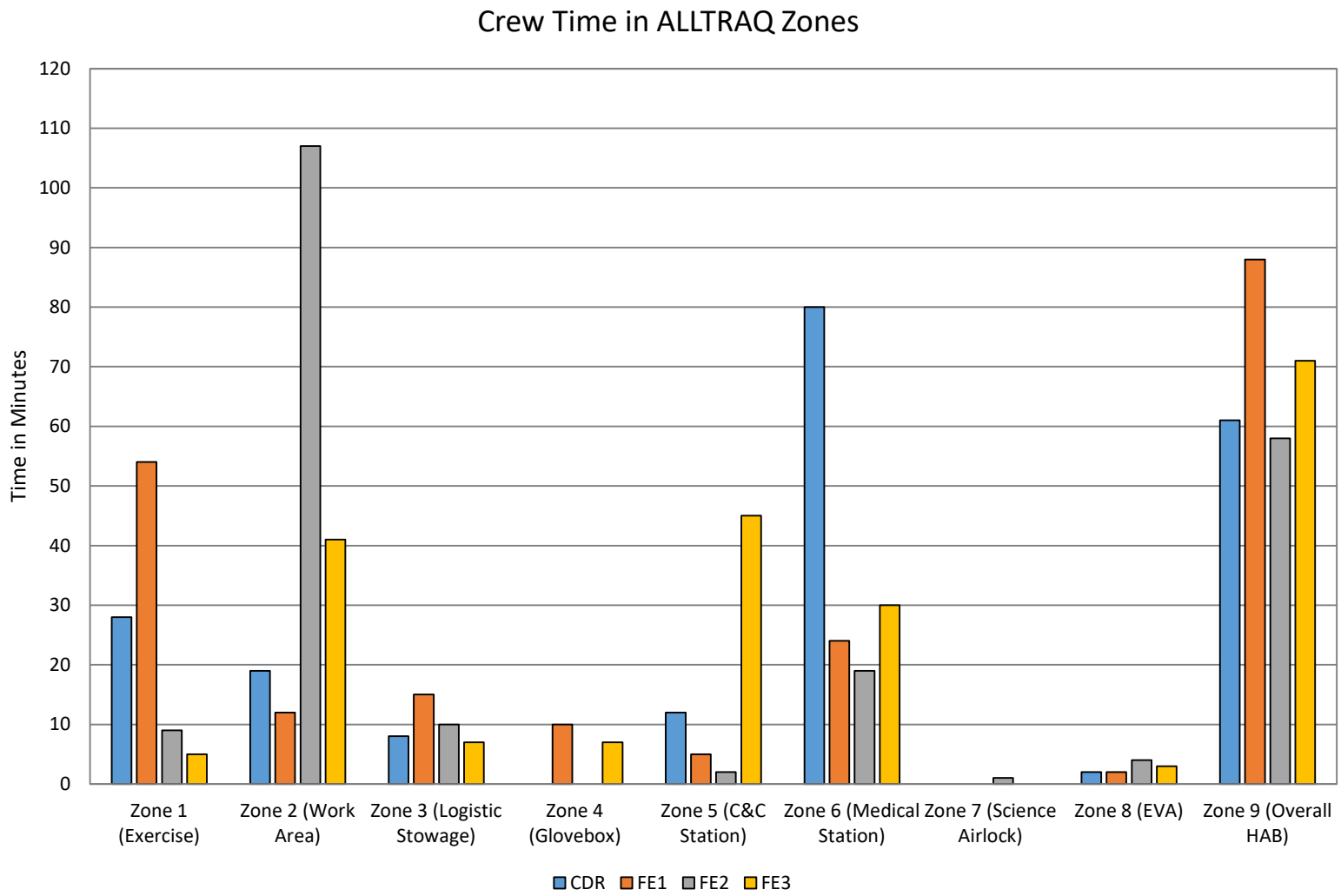
- **Movement Zones**

9 zones have been created for this test



ALLTRAQ

- **Overall crew time spent in zones**



Example Acceptability Questionnaire - Exercise

1. Rate the sim quality and acceptability of the following habitation characteristics for this vehicle:

Definitions to consider when scoring:
Operability - The design is ready for use such as deploying or stowing.
Accessibility - The quality of being able to be easily reached or obtained for use.
Functionality - The purpose that something is designed or expected to fulfill the design.
Usability - The degree to which something is able or fit to be used by the operator.

		SIM QUALITY RATING					ACCEPTABILITY RATING										Comments (REQUIRED IF SIM ≥ 3 OR ACCEPTABILITY ≥ 4)
		1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	
a.	Ability to access and locate the HAB exercise equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
b.	Setup of HAB exercise equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
c.	Volume to perform aerobic exercise	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
d.	Volume to perform resistive exercise	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
e.	Accessibility to non- exercising crew member to other areas within the HAB	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
f.	Exercise equipment breakdown and stowage within HAB	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
g.	Overall acceptability of exercise within HAB	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Notional

Example Acceptability Questionnaire – Multi-Purpose Workstations

1. Rate the sim quality and acceptability of the following habitation characteristics for this vehicle:

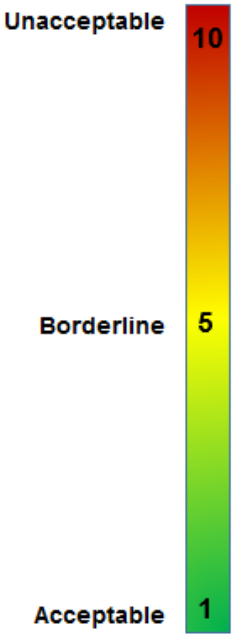
Definitions to consider when scoring:
Operability - The design is ready for use such as deploying or stowing.
Accessibility - The quality of being able to be easily reached or obtained for use.
Functionality - The purpose that something is designed or expected to fulfill the design.
Usability - The degree to which something is able or fit to be used by the operator.

		SIM QUALITY RATING					ACCEPTABILITY RATING										Comments (REQUIRED IF SIM ≥ 3 OR ACCEPTABILITY ≥ 4)
		1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	
a.	Physical location of workstation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
b.	Overall work volume of the workstation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
c.	Accessibility to the workstation's displays and controls	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
d.	Usability of the workstation's displays and controls	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
e.	Accessibility to the workstation's display edge keys	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
f.	Adjustability of the display(s)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
g.	Lighting within the workstation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
h.	Accessibility to hand controllers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
i.	Accessibility of horizontal work surfaces for the workstation (e.g. keyboard tray)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
j.	Workstation setup	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
k.	Acceptability of the mulit-purpose workstation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Notional

Acceptability Ratings

DSG Architectural Configuration Acceptability Ratings



	A	B	C	D	E
Robotic arm ops	2	8	9	3	9
EVA prep	6	10	2	6	1
EVA	7	3	6	1	8
Meal prep	9	10	6	9	1
Hygiene	1	2	7	6	7
WCS ops	5	4	7	3	2
Suit Stowage	3	3	7	4	8
Sleeping	5	6	2	8	9
Docking and berthing	10	5	2	6	5
Logistics/Trash Stowage	7	6	7	5	10
Simulated contingencies	4	9	1	4	2
Experimental science	6	6	4	5	8
House keeping	2	5	2	3	5
Routine maintenance	2	7	1	4	9
IFM	5	8	7	10	6
Exercise	4	5	10	5	8
PAO	3	10	5	3	10
Medical	7	9	2	5	2

Acceptability Ratings < 4

Acceptable Configurations	Most Acceptable Configuration
A, D	A
C,E	E
B,D	D
E	E
A,B	A
B,D,E	E
A,B,D	A or B
C	C
C	C
None	None
A,C,D,E	C
C	C
A,C, D	A or C
A,C,D	C
None	None
A	A
A,D	A or D
C,E	C or E

NOTIONAL

Example Capability Questionnaire

1. *Sim quality should be provided first before considering capability. If simulation quality is inadequate to meaningfully evaluate the aspect, a sim quality rating of 4 or 5 should be provided and comments must be added that indicate the reason for the inadequate sim quality. If the sim quality is adequate for evaluation (i.e. 1-3), provide an capability rating for that aspect. If an aspect is rated anything but essential/enabling (i.e. if a rating of 3-10 is given), comments must be provided that indicate the level of significance enhancment.*

		SIM QUALITY RATING | CAPABILITY RATING															Comments (REQUIRED IF SIM ≥ 3 OR CAPABILITY ≥ 4)
		1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	
a.	A WCS in a different module from the galley	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
b.	An additional WCS separate from Orion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
c.	An additional galley separate from Orion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
d.	Trash ejection on a per mission basis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
e.	Trash ejection on a per weekly basis	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
f.	Multiple, dedicated temp stow areas for trash	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
g.	Separate wet and dry trash stowage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
h.	Two multiipurpose workstations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
i.	A dedicated medical area	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
j.	A dedicated science module	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
k.	A hardwired multi-puprose station for critical commanding	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
l.	Two exercise stations	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
m.	A permanently installed exercise	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Notional

Capabilities Assessments

Analytical Hierarchy

Instructions:

For each of the listed capabilities, assign an "X" to indicate which capability in a row is more important than the capability in the column for the specific test condition (i.e. HAB-HAL). You can have more than one "X" per row.

Selection Criteria "X" Indicates Row more Important Than Column		WCS		Galley	Trash Management			Workstation	Medical	Science	Command & Control	Exercise			Sleep Station	Logistics			Lighting	Windows
		A WCS in a different module from the galley	An additional WCS Separate from Orion	An additional galley separate from Orion	Trash ejection on a per mission basis	Trash ejection on a per weekly basis	Multiple dedicated temp stow areas for trash	Separate wet and dry trash stowage	Two multi-purpose workstations	A dedicated medical area	A dedicated science module	A hardwired multi-purpose station for critical commanding	Two exercise stations	A permanently installed exercise station	Exercise station in separate module from the main habitat	Private sleep stations	A dedicated logistics module	A logistics module sized for a single mission	A deterministic logistics stowage system (i.e. labeled lockers)	Circadian cycle lighting system	A viewing window (not a virtual window)
WCS	A WCS in a different module from the galley																				
	An additional WCS Separate from Orion																				
Galley	An additional galley separate from Orion																				
Trash Mangement	Trash ejection on a per mission basis																				
	Trash ejection on a per weekly basis																				
	Separate wet and dry trash stowage																				
Workstation	Two multi-purpose workstations																				
Medical	A dedicated medical area																				
Science	A dedicated science module																				
Command & Control	A hardwired multi-purpose station for critical commanding																				
Exercise	Two exercise stations																				
	A permanently installed exercise station																				
	Exercise station in separate module from the main habitat																				
Sleep Station	Private sleep stations																				
Logistics	A dedicated logistics module																				
	A deterministic logistics stowage system vs CTBs (i.e. labeled lockers)																				
Lighiting	Circadian cycle lighting system																				
Windows	A viewing window (not a virtual window)																				

Notional

May Ground Test Early Lessons Learned

- **It is a lot of work to put together all the mission content and ground support infrastructure to support an integrated test.**
  - We have been working on preparations for this single test for 8 months and are still not quite ready
- **The importance of performing a dry "engineering run" before the formal crew run.**
- **Some of the stakeholder mission content does not fit well within the constraints of the timeline and potentially adversely affects the evaluation of the habitats.**
  - Understanding of priorities with regards to core ground test objectives and not overpromising stakeholders.
- **Based on December test and multiple reviews we have significantly refined/revised the questionnaires and capability assessment ratings.**
- **To develop flight-like procedures and mission content takes far more time than most people understand.**
- **We need to maintain flexibility to work with crew office scheduling**
- **We are behind the curve with respect to developing the contractor specific timelines, questionnaires, and test plans.**
  - Recommend within 1-month we develop draft timelines for each contractor that incorporate as much of our core mission content that has already been developed as possible, while leaving the flexibility to arrange the sequence of tasks and allowing for some contractor unique content.

Backup

59